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ENERGY COMMISSION**



California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

The EV Project: Electric Drive Vehicle Demonstration and Infrastructure Evaluation in the San Diego Region

Prepared for: California Energy Commission

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Gavin Newsom, Governor

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- City of Santee
- Cleantech San Diego
- County of San Diego
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- Car 2 Go
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- Unified Port of San Diego
- University of California at San Diego

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to \$20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about \$100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued solicitation PON-08-010 to provide funding opportunities for early market transportation electrification projects that were also funded by the U.S. Department of Energy under the American Reinvestment and Recovery Act of 2009 (ARRA). In response to PON-08-010, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards April 22, 2009. The agreement was executed as ARV-09-005 on April 15, 2011.

Note that a separate volume of technical appendices is available on request.

ABSTRACT

The EV Project was a real-world study of the deployment and use of charging infrastructure and Plug-In Electric Vehicles (PEVs). It was performed at the very beginning of the first widespread sale of PEVs in US history. The results of the study of the deployment process in San Diego County and the use of the charge infrastructure both at home and away-from-home, will inform California governments, business & industry and citizens on how it was done, how it was used, and hopefully how best to deploy charging infrastructure that gets used more often and promotes the ongoing adoption of PEVs.

This project planned, permitted, installed, operated, collected data and reported on the use of over 1,500 chargers. It collected data from 1,339 PEVs that used this charge infrastructure.

These vehicles operated over 18,200,000 electric miles and generated data from over 600,000 distinct charge events during two years of an expanding charging landscape.

The resulting reports, charts, graphs and maps provide information that allows the reader to observe the changing PEV and charging landscape as it actually happened. This report takes the reader back to understand what was done, why it was done and what can be learned from the experience.

Finally, the project leaves a legacy of charging infrastructure in place at California homes and businesses for PEV drivers to continue to use helping to pave the way for a more sustainable personal transportation future for California's citizens.

Keywords: EV Project, electric drive, charging infrastructure, battery electric vehicles, plug-in electric vehicles, California Energy Commission, ARRA, San Diego.

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EXECUTIVE SUMMARY

The EV Project was the largest electric vehicle infrastructure demonstration project ever undertaken (at its inception in 2008). The EV Project was funded as a 50/50 cost share reimbursement grant as part of the American Recovery and Reinvestment Act (ARRA) of 2009. Electric Transportation Engineering Corporation (doing business as ECotality North America (ECotality)) was awarded this federal grant as the result of a competitively bid Federal Funding Opportunity Announcement (DE-FOA-028). The CEC awarded ECotality an \$8 million grant from the ARFVTP's first Investment Plan, which was used to help ECotality meet its cost share obligation and ensure the participation of California cities in this historic EV infrastructure study. ECotality contributed \$9.8 million in private matching funds. The target region of the EV infrastructure deployment and assessment funded under this grant was San Diego, California, which was one of the earliest and largest EV Project deployments in the U.S. The U.S. Department of Energy funded other EV Project deployments throughout California and the country.

The EV Project had two primary goals. The first was to deploy charging infrastructure for both home and away-from-home use in a deliberate manner so as to understand the characteristics of the charging location, and to understand the circumstances associated with the installation process.

The second goal was to collect data on the use of the deployed infrastructure and the vehicles that used it, and to analyze this data in order to better understand how vehicles and infrastructure were used. Ultimately this analysis could lead to understanding how or where best to deploy infrastructure to maximize its use and the benefit to the public.

An important part of the efforts to deploy charging infrastructure was in the planning. This project engaged stakeholders in the region from local government, academia, industry, the electric utility and employers. This report explains the planning process undertaken, the effectiveness of the plan, the utilization of the deployed infrastructure and the things that hindered the project's ability to complete the plan.

Through these planning efforts, the first goal (deployment of infrastructure) needed to keep in mind the second goal (collecting data on the use of the vehicles and infrastructure) as not only did the charging hardware need to be able to collect data on its use, but the installation location could not disrupt or disable the data communication. A combination of internet and cellular data communications were used for charging infrastructure data transmission along with vehicle use data collected by PEV partners Nissan and Chevrolet through their existing onboard systems, CarWings and OnStar. These three data streams were transmitted to the Idaho National Laboratory (INL), where they were assembled, filtered and organized into usable information for analysis.

Examination and analysis of the data by the INL created quantitative and qualitative information that could then be used to understand the barriers to deployment, best practices and lessons learned.

In addition to INL, the National Renewable Energy Laboratory (NREL) in Colorado contributed important use data and analyses. The Institute for Transportation Studies at the University of California, Davis also made important analytic contributions to the study.

The information and observations made from the collected data was published for future Electric Vehicle (EV) owners, legislators, local jurisdictions, and charging infrastructure hosts to replicate or improve upon for future infrastructure deployment, for product design, and for network design.

In the end, 953 Leaf and Volt drivers received home chargers in exchange for their participation in collecting data on their use of their Plug-In Vehicle and the charging infrastructure installed to serve them. In addition, 552 Level 2 charging units were installed in locations away-from- home in order to support these study participants’

In the end the following deployment and data collection levels were achieved in this project’s study area:

- Deployed 1,026 residential AC Level 2 EVSE
- Deployed 552 public AC Level 2 EVSE
- Deployed 7 DCFC
- Collected data on 633,063 Charging Events
- Collected data from 681 Nissan Leafs
- Collected data from 272 Chevrolet Volts
- 386 Car2Go vehicles participating
- 18,288,000 electric miles accumulated on project vehicles
- Collected and transmitted to INL utilization data from 2,899 discrete sources of data

As shown in Table ES1, the Nissan Leaf, Chevrolet Volt and SmartForTwo EVs and PHEVs accumulated over 18 million electric-mode miles, avoided more than 600,000 gallons of gasoline and avoided nearly 6.5 million pounds of carbon dioxide-equivalent (CO₂e).

Table ES1: San Diego EV Project Petroleum and Carbon Reduction Benefits

Vehicle	No. of Vehicles	Total Electric Miles	Total Petroleum Reduction (gallons)	Total Avoided Carbon Emissions (lbs. CO₂e)
Nissan Leaf	681	12,500,000	437,000	4,968,500
Chevrolet Volt	272	3,088,000	97,400	959,400
SmartForTwo/ Car2Go	386	2,700,000	75,000	561,500
Totals	1,339	18,288,000	609,400	6,489,400

Source: Blink Network

The analysis of data took place in a changing environment (i.e. there were “zero” vehicles and “zero” charging units at the start, followed by the deployment of the above over two years). Analysis of the data must be mindful of this important condition. The commercial lease of the Nissan Leaf in 2010 provided the initial volume of electric vehicles necessary to study the EV owners’ interaction with publicly available EVSE.

Although the project did not fully deploy the total number of units that it intended, it did successfully achieve the objective of collecting data on the deployment process, data from vehicles operating in the study area, and data from the use of deployed units.

Therefore, the project should be seen as a success with hundreds of charging units deployed for use by the project, hundreds of units left to benefit the public and promote EV adoption, it collected 100 percent of the intended data parameters, and the project achieved these milestones while meeting cost share objectives and spending less than 70 percent of the allocated budget.

In September 2013, ECotality declared bankruptcy. Most of the infrastructure had already been deployed, use data from millions of miles of EV travel and charge events were collected, and many Lessons Learned documents had been published. Blink Network LLC acquired assets in the bankruptcy auction that enabled them to continue to collect data on use of the Blink network of chargers and deploy additional EV charging infrastructure. Blink successfully completed The EV Project work funded by the Energy Commission.

Chapter 1: Introduction and Background

Introduction

The purpose of the EV Project was to leverage the American Recovery and Reinvestment Act (ARRA) of 2009 for the benefit of California residents. Funding from the CEC could be used by selected recipients of ARRA awards as match share for their Federal grant, which would attract the most worthwhile of these national projects and their federal funding to California. This would help California to create/retain jobs and to invest in vehicle electrification.

Authorization

Assembly Bill 118 (Nunez, Chapter 750, Statutes of 2007), created the Alternative and Renewable Fuel and Vehicle Technology Program (now known as the Clean Transportation Program). The statute, subsequently amended by AB 109 (Nunez, Chapter 313, Statutes of 2008), authorizes the CEC to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. The CEC has an annual program budget of approximately \$100 million and provides financial support for projects that:

- Develop and improve alternative and renewable low-carbon fuels;
- Optimize alternative and renewable fuels for existing and developing engine technologies;
- Produce alternative and renewable low-carbon fuels in California;
- Decrease, on a full fuel cycle basis, the overall impact and carbon footprint of alternative and renewable fuels and increase sustainability;
- Expand fuel infrastructure, fueling stations, and equipment;
- Improve light-, medium-, and heavy-duty vehicle technologies;
- Retrofit medium- and heavy-duty on-road and non-road vehicle fleets;
- Expand infrastructure connected with existing fleets, public transit, and transportation corridors; and
- Establish workforce training programs, conduct public education and promotion and create technology centers.

The CEC issued solicitation PON-08-010 to provide funding opportunities under ARFVTP for projects which have been awarded funding from the DOE under a federal funding opportunity announcement for specified transportation electrification projects. To be eligible for funding, under PON-08-010, the projects must also be consistent with the Energy Commission's *AB 118 Program Investment Plan*. In response to PON-08-010, Electric Transportation Engineering Corporation submitted application number 18, which was awarded Grant Award Number ARV-09-005. The CEC contracted with Blink Network LLC to complete the work after the dissolution of Electric Transportation Engineering Corporation.

Figure 1: CEC Headquarters in Sacramento, CA



Source: California Energy Commission

The original Problem Statement in 2009 read:

With production EVs available next year, the lack of infrastructure to support these vehicles is now a barrier to their widespread adoption and the realization of the potential they provide for petroleum reduction. The proposed EV Project takes advantage of the initial availability of Nissan EVs to develop, implement and study techniques for optimizing the effectiveness of infrastructure supporting widespread EV deployment. By studying and developing lessons learned from the infrastructure supporting these first 5,000 vehicles, the proposed Project enables deployment of the next 5,000,000 vehicles.

Objectives of the Agreement

The objectives of this Agreement were to:

- Gather data from PEVs and Electric Vehicle Supply Equipment (EVSE)
- Deploy AC Level 2 charge infrastructure in residential applications to support EV sales in County of San Diego
- Deploy AC Level 2 charge infrastructure in commercial applications to support EV sales in County of San Diego
- Deploy DC fast charging (DCFC) infrastructure to support EV sales in the County of San Diego
- An agreement amendment later added Orange County to the study area.

Background

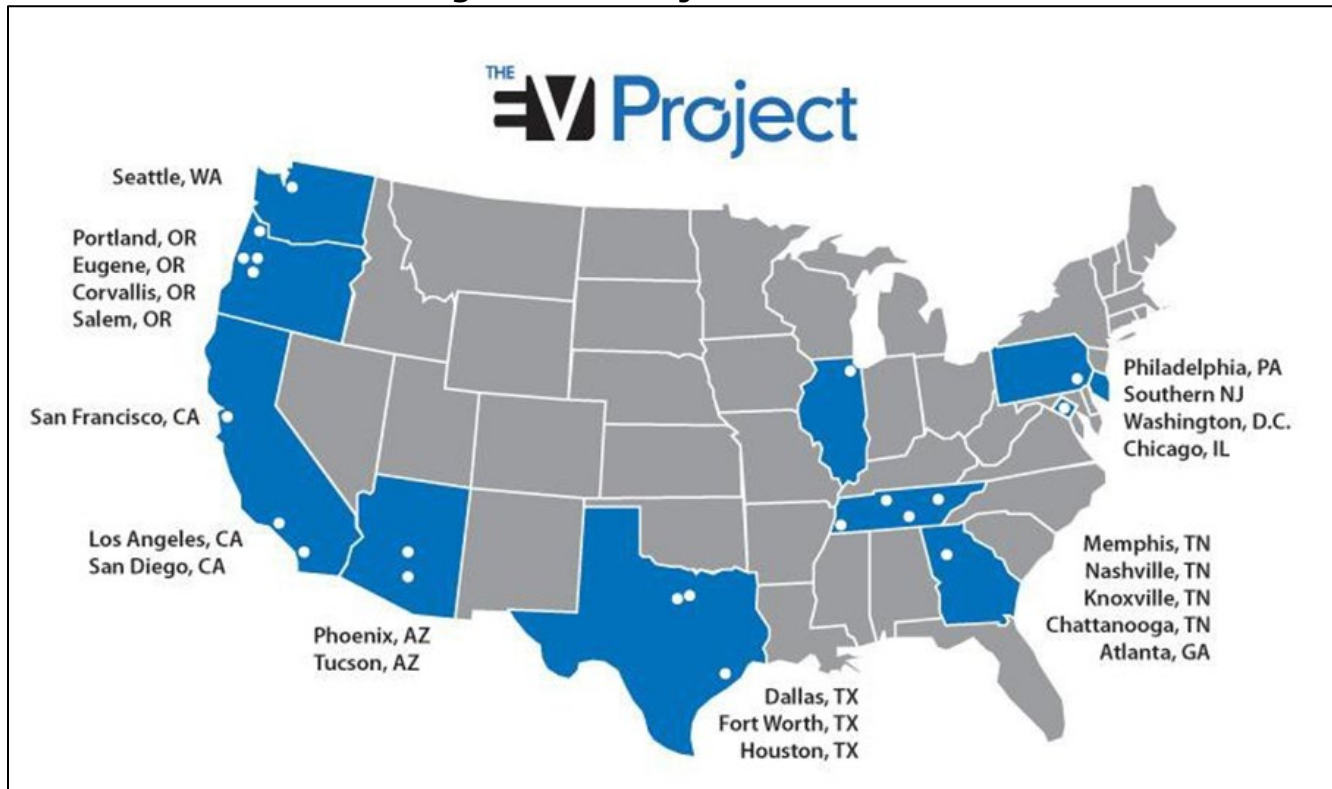
The EV Project was the largest electric vehicle infrastructure demonstration project ever undertaken. The EV Project was funded as a 50/50 cost share reimbursement grant as part of the American Recovery and Reinvestment Act of 2009. Electric Transportation Engineering Corporation (doing business as ECotality North America (ECotality)) was awarded this federal grant as the result of a competitively bid Federal Funding Opportunity Announcement (DE-FOA-028). The CEC awarded ECotality an \$8,000,000 grant from the ARFVTP's first Investment Plan, which was used to help ECotality meet its cost share obligation and ensure the participation of California cities in this historic EV infrastructure study.

The commercial release of the Nissan Leaf in 2010 provided the initial volume of electric vehicles necessary to study the EV owners' interaction with publicly available EVSE. There is long-standing debate related to EV charging infrastructure. Are publicly accessible charging locations necessary for widespread adoption of EVs? Will the widespread adoption of EVs drive business owners to install charging stations in order to attract EV driver/customers?

ECotality originally proposed the deployment, demonstration and evaluation of approximately 4,700 battery electric vehicles (BEVs) in each of five metropolitan areas in the continental U.S. In conjunction with the Nissan vehicle rollout, ECotality planned to develop the infrastructure to support these vehicles, including residential charging, commercial charging and public charging. Data collected from both the vehicles and chargers would assist in assessing the impacts of factors, which have a potential to influence vehicle design, such as vehicle use patterns, charging frequency, varying climates, availability of vehicle chargers, real-world electric range, and overall operating cost. Evaluation of these impacts leads to "lessons learned", which when implemented support efforts to optimize vehicle and charge use. As a result of the CEC funding through ARV-09-005, San Diego was designated as one of the original study markets included in the EV Project.

The EV Project later expanded to include another 1,000 Leafs and approximately 2,600 Chevrolet Volt extended range electric vehicles (EREV) produced by General Motors and the project boundaries expanded to include 23 major metropolitan areas in 9 states plus the District of Columbia. See Figure 2.

Figure 2: EV Project Locations¹



Source: Blink Network

In September 2013, ECotality declared bankruptcy. Most of the infrastructure had already been deployed, use data from millions of miles of EV travel and charge events were collected, and many Lessons Learned documents had been published. Blink Network LLC acquired assets in the bankruptcy auction that enabled them to continue to collect data on use of the Blink network of chargers and deploy additional EV charging infrastructure.

¹ [EV Project Overview](https://www.energy.gov/eere/vehicles/avta-ev-project) <https://www.energy.gov/eere/vehicles/avta-ev-project>
[accessed March 21, 2014]

Chapter 2: Approach

Planning Approach

Nissan and Chevrolet projected the commencement of EV sales in the fall of 2010. That schedule provided approximately one year from the start of the EV Project to prepare the design, development, procurement and deployment of the EVSE to support these EVs. The original project completion was targeted for December 2012 so planning for the deployment of EVSE, data collection and evaluation required completion in just two years. With approximately 8,300 Nissan Leafs and Chevrolet Volts and approximately 5,000 publicly accessible AC Level 2 EVSE and DCFC, how and where the EVSE should be deployed was not a trivial task and time was short. Planning this deployment included planning for the needs of the residential participants, coordination with the vehicle suppliers, planning for the locations for the publicly accessible EVSE, design and production of EVSE as well as the development of the contractor network necessary to install these EVSE.

Residential EVSE Planning

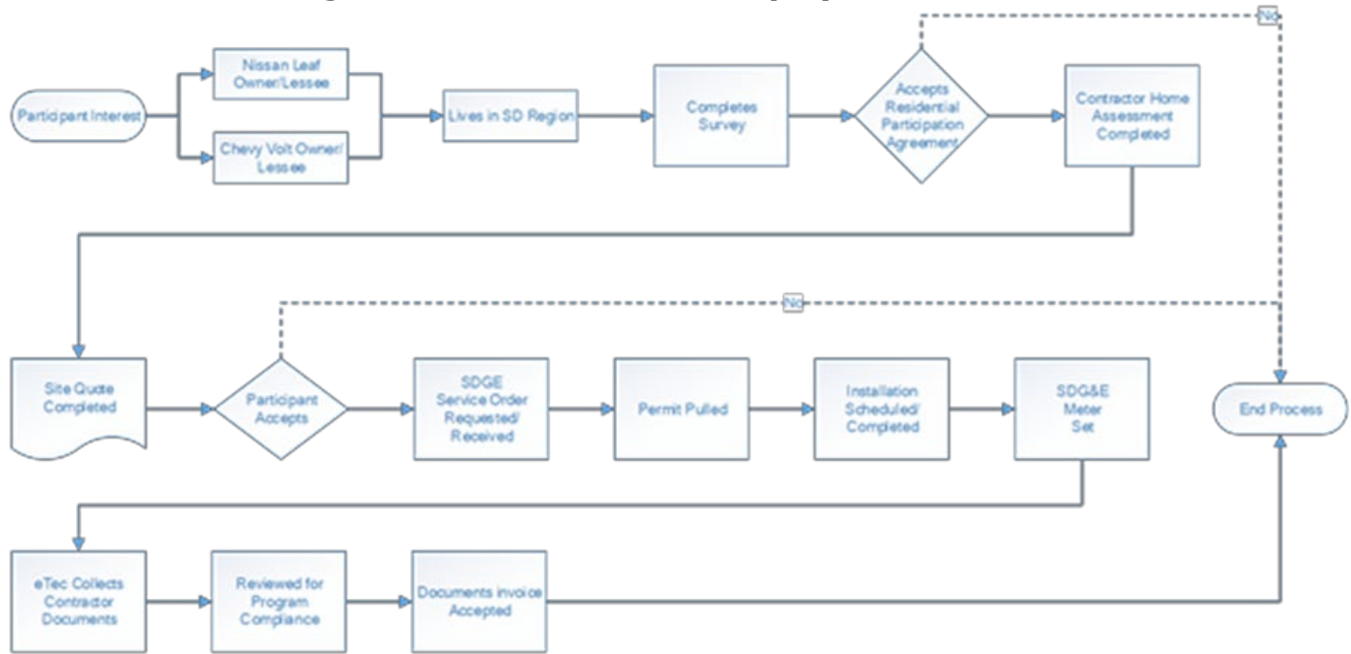
The Greater San Diego area is one of the original project areas for the EV Project. While Nissan and General Motors prepared their dealer networks for vehicle delivery, the EV Project began preparations for accepting residential participants into the study.

The EVSE delivery and installation process, outlined in Figure 3, involved the vehicle dealers, certification of participant eligibility, participant acceptance of involvement, contractor installation estimates, completion of the vehicle sales process, permitting and installation of the EVSE and document closeout. In the San Diego region, coordination with the electric utility, San Diego Gas and Electric (SDG&E) was also required. All residential participants simultaneously enrolled in the SDG&E rate study requiring installation of their EVSE on a separate residential circuit monitored by a second electric meter.

Vehicle Coordination Planning

The sales processes employed by Nissan and General Motors differed greatly. Nissan established a prospect list early in 2010 well before vehicles production commenced. General Motors sold vehicles as they became available in the dealer showrooms. For both providers, the addition of EVSE to the sales process was a new feature. Traditionally, the vehicle sale completes as the vehicle exits the dealer's lot but, especially for the Leaf, the delivery and installation of the EVSE in the vehicle owner's home was required within a few days of the vehicle delivery. In some cases, the cost of the EVSE and installation was included in the vehicle sale. This required advanced notice, EVSE availability, contractor scheduling, owner commitments and coordination past vehicle delivery. The vehicle suppliers were also concerned about customer satisfaction related to this installation that was frequently beyond their control. The vehicle suppliers and ECOtality closely monitored this customer satisfaction.

Figure 3: Residential EVSE Deployment Process



Source: Blink Network

Both Nissan and General Motors required certification and control of the installation contractors. Nissan accepted the ECotality Certified Contractor Network and General Motors required installation by SPX (later acquired by Bosch).

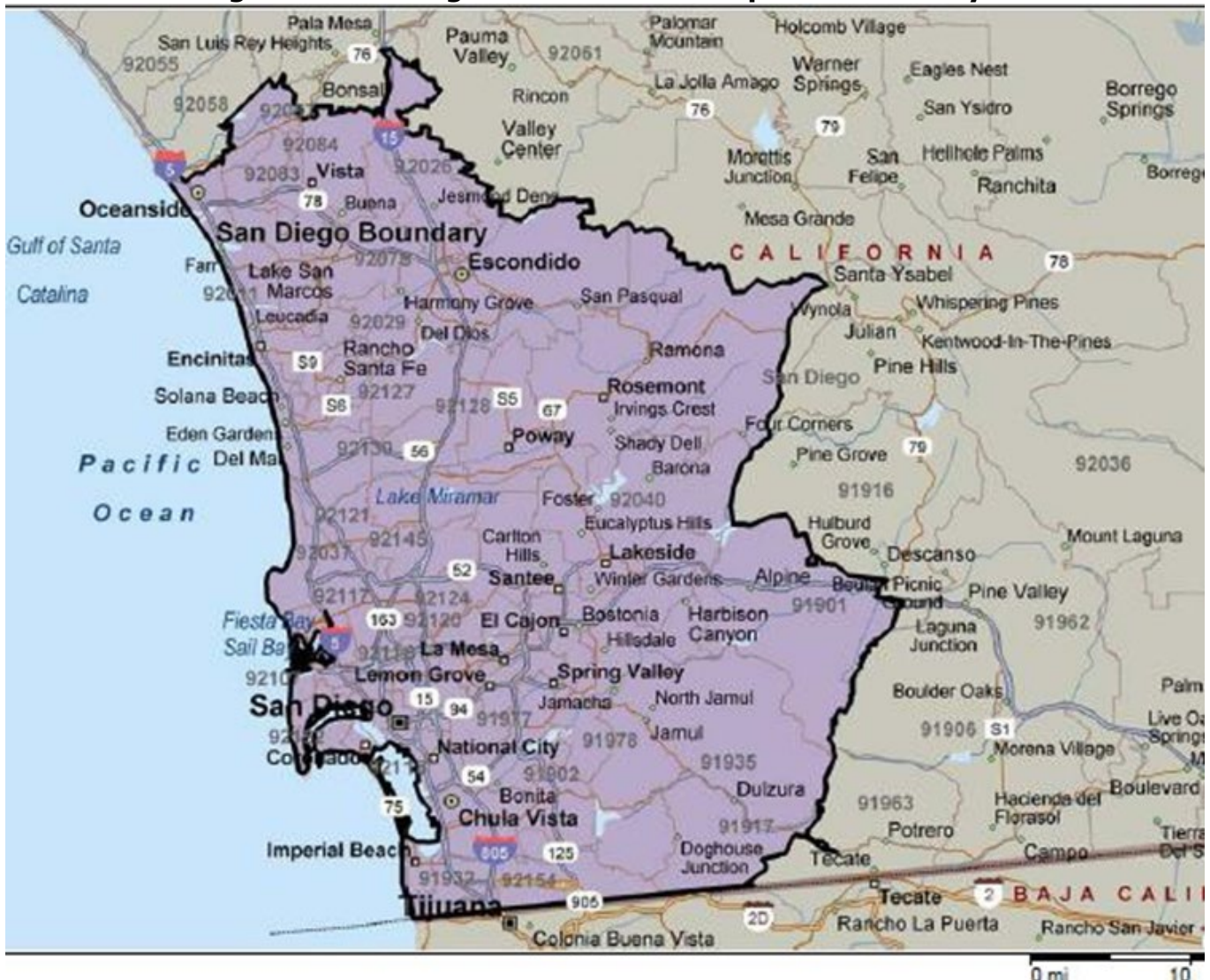
Nissan and ECotality integrated their Customer Relations Management (CRM) systems to provide for direct updating of a customer's progress in the procurement of the EV and EVSE installation. ECotality received approximately three weeks' notice of the impending delivery of the Leaf - during which time, ECotality coordinated with the residential contractor network (See below) to conduct a home inspection and installation cost estimate. The prospect accepted the installation estimate, the terms and conditions of participation agreement and took delivery of the vehicle prior to the final EVSE installation.

Residential Participation Planning

Because a significant amount of vehicle charging takes place at EV driver residences, a portion of The EV Project funding supported residential EVSE. Participants received the residential EVSE and credit toward the cost of installation in exchange for allowing the collection of vehicle and charge information at home and publicly available EVSE for the duration of the project.

This information included data from both the vehicle and the EVSE, such as energy used and time and duration of charger use. The study identified a test boundary in the greater San Diego area shown in Figure 4.

Figure 4: San Diego Residential Participation Boundary



Source: Blink Network

Nissan conducted all of their initial sales efforts on-line with interested parties entering a waiting list. As part of that process, the EV Project prospect completed a survey related to their residence and its ownership and construction. The survey responses provided qualification criteria for acceptance as a participant. Participants must live within the EV Project zip codes, purchase or lease a Leaf or Volt, own their own residence and agree to the terms of the Residential Participation Agreement that identified the data requirements and terms.

Assuming compliance with the Residential Participation Agreement, the EVSE would remain the property of the participant when the project completed.

Revisions to the Residential Participation Agreement were required when the project expanded to include the General Motors Volt and the termination date extended to December 31, 2013. Some participants declined to continue the benefits of participation past the original date in 2012 and were "retired" from the project.

Commercial EVSE Planning

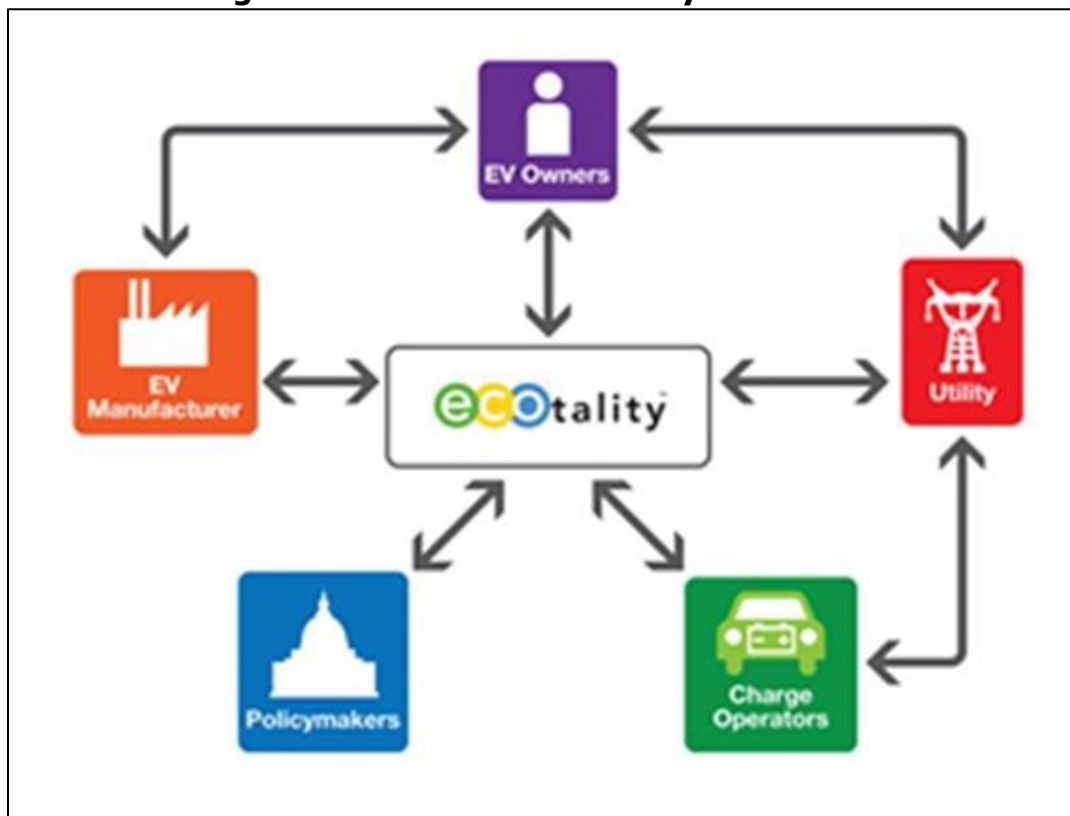
The availability of the Nissan Leaf in full commercial production provided an opportunity to develop and study a “rich charge infrastructure” typical of a fully mature EV environment. The project sought to develop such “rich charge infrastructures” in the San Diego region, allowing data to be collected characterizing the full utilization of charge infrastructure, the interaction between vehicle use and charger availability, the effectiveness of various revenue collection methods for public charging, the interaction of charge infrastructure with the electric grid and the effectiveness of various charge infrastructure locations.

The effectiveness of the charging locations is one of the key questions addressed by this project. Thus, location planning was the significant effort undertaken during 2010.

Stakeholder Involvement

Understanding the local commercial and personal demographics is essential in effective planning EVSE locations. ECotality assigned an Area Manager to lead and facilitate the publicly accessible EVSE planning process. The Area Manager worked with key local leaders to identify and organize a group of community stakeholders to form an advisory group. These community stakeholders had demonstrated leadership and interest in the deployment of EVs. Figure 5 shows the stakeholder advisory committee.

Figure 5: Stakeholder Advisory Committee



Source: Blink Network

The San Diego advisory group consisted of representatives from the following organizations:

- California Center for Sustainable Energy
- City of Chula Vista
- City of Escondido
- City of La Mesa
- City of Oceanside City of Poway
- City of San Diego
- City of Santee
- Cleantech San Diego
- County of San Diego
- Miramar College Qualcomm
- San Diego Association of Governments (SANDAG)
- San Diego Gas & Electric
- San Diego State University
- Sequoia Solar
- Unified Port of San Diego
- University of California at San Diego

This group followed the EV Micro-Climate™ planning process developed by ECOTality to accomplish the location planning. Further discussion of this process is included in Section 3.

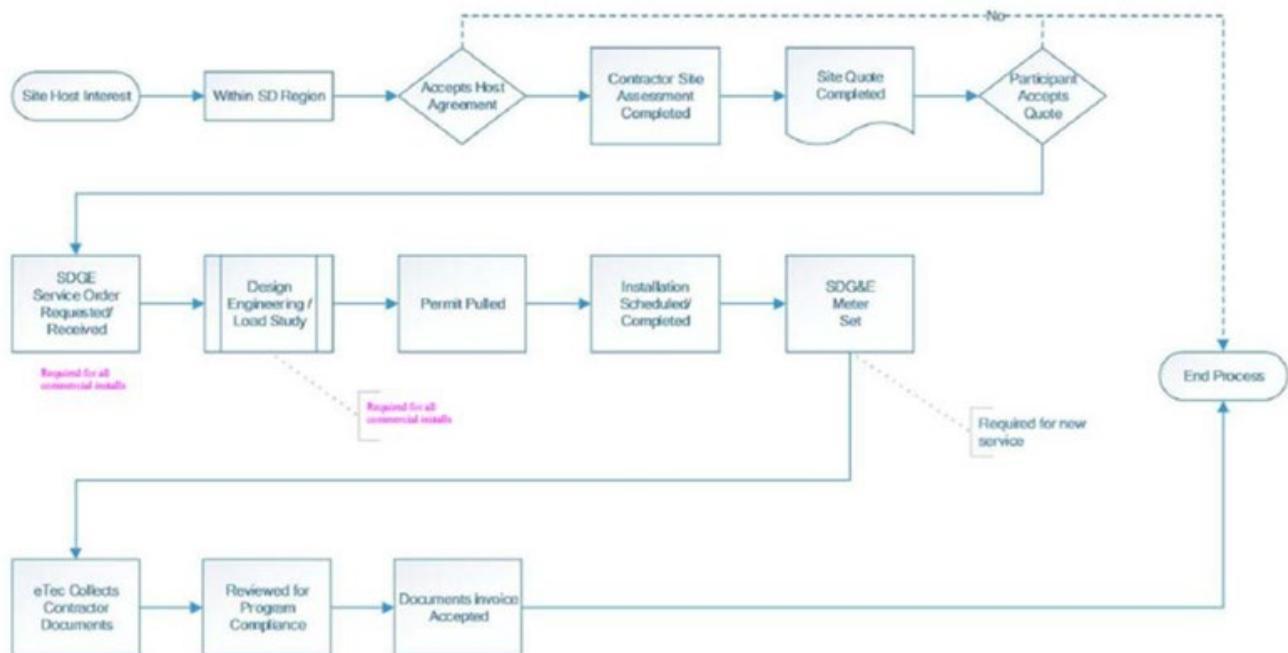
In the initial stages of this deployment, the focus of away-from-home charging was on publicly accessible EVSE. Because of the slower than expected uptake by hosts for publicly accessible chargers and growing interest for fleet and workplace applications and interactions, the EV Project increased the number of approved installations for these applications. Note: Throughout this paper, the terms “commercial”, “away-from-home”, and “non-residential” EVSE are equivalent to the collective fleet, workplace and publicly accessible designations.

Non-Residential Contract Development

Deploying the publicly accessible EVSE required the support and interest of the charging site host. These hosts included private business, public and governmental entities. Because early deployment of these EVSE occurred in an environment with few EVs in operation, these EVSE experienced light utilization in the early deployment. A portion of the EV Project funding supported this non-residential EVSE deployment. Charging site hosts received the public AC Level 2 EVSE and credit toward the installation in exchange for allowing the collection of charge information for the duration of the project. Following project completion, the host had the option of retaining and owning the EVSE or requesting its removal.

The deployment of non-residential EVSE essentially followed the process shown in Figure 6.

Figure 6: Non-Residential EVSE Deployment Process



Source: Blink Network

As with residential EVSE planning, a project test boundary was required for non-residential EVSE planning. The boundary started with that identified for residential participation (Figure 4 above) plus zip codes that were directly adjacent to residential boundary areas and locations of interest outside this boundary that would attract EV owners (e.g. transportation hubs, entertainment venues, significant employers).

The installation of non-residential EVSE followed the typical requirements of the local Authority Having Jurisdiction (AHJ) for permits, engineered drawings and so forth. The Blink EVSE provided the opportunity for revenue from access fees and advertising. Contracts between the EV Project and the charging site host were prepared governing the terms for installation support funding, data collection, revenue sharing, advertising support, participation through the end of the project as well as other typical contractual requirements.

DCFC Planning

DCFC planning essentially followed the process for non-residential planning with a few exceptions. The value of the DCFC was such that federal government property guidelines prevented the asset from becoming the property of the charging site host at the end of the study period and ECOTality retained ownership. Installation was more complex and the electrical supply requirements required greater coordination with the local electric utility, SDG&E.

DC fast charging was a fairly new concept in PEV charging. Prior releases of PEVs in the U.S. did not include DCFC and U.S. standards did not exist. Nissan initiated the concept in Japan and conducted early studies with Tokyo Electric Power Company employees. Anecdotal reports indicated that employee confidence in vehicle range increased just by knowing the DCFC provided backup recharge capabilities even though this confidence did not translate into actual DCFC usage.

With no prior history with DCFC usage, planning started with no real statistical data. Previous experience with publicly accessible AC Level 2 EVSE provided some initial planning direction but such was absent for DCFC. In addition, uncertainty existed relative to the experience in Japan. What is the function of the DCFC? Would drivers use it? The DCFC charge port in the Nissan Leaf was an option so would buyers elect the option? Without the port, the availability of DCFC was meaningless.

In order to test DCFC as part of the infrastructure, the EV Project contracted with Nissan to provide the DCFC port on all participant vehicles. The EV Project also identified a quantity of DCFC ports for deployment in areas where these DCFC equipped Leafs deployed.

DCFC were planned to provide three basic purposes: backup for local publicly accessible AC Level 2 EVSE in providing range confidence, range extension in transportation corridors and, although not in the project scope, recharge capabilities for those in multi-family dwellings.

Planning efforts then concentrated on the first two functions.

Transportation corridors exist between several project territories. In Tennessee, Nashville, Knoxville and Chattanooga form a corridor triangle. Phoenix and Tucson in Arizona and Los Angeles and San Diego also provide corridors. The distances between Seattle and Portland were too great to be a corridor in the project as were Dallas and Houston.

By the time of the project expansion to Atlanta, Philadelphia and Chicago, all DCFC resources were assigned and no further expansion occurred.

Stakeholder Involvement

PEV driver usage of DCFC differs from AC Level 2 in that the recharge time is significantly shorter and the driver is likely to remain close to the vehicle while charging. Thus, locations where short stays occur are more suitable. Fast food restaurants, convenience stores, refueling stations, rest stops, coffee shops and the like are potential hosts.

The power required by DC Fast Charging is more typically available in industrial areas and may not be readily available in all typical commercial or public areas. Industrial users require the higher power availability to power equipment, lights, material handling equipment, battery charging equipment, freezers and other very heavy loads. The electric utility provides this power through the transformers in the area and is one reason areas are zoned for industrial applications. Thus, the local electric utility must have a significant role in the planning efforts and SDG&E provided great assistance in the San Diego planning effort. The planning documents generated by the advisory group included DCFC planning.

Commercial Contract Development

Installation of DCFC followed the process required by the AHJ. The DCFC power requirements could have a significant impact on the charging site host's electrical costs. The 60 kW rating of the DCFC had the real potential to cause the increased costs of higher demand charges and the high charge rates contributed to increased kWh utilization. Both had the potential for significant impact to the host and required additional language in the contract to address responsibilities for these costs. Because installation was more complex, additional resources from the EV Project provided incentive to the host.

Blink's EVSE Design

In 2010, there were several EVSE Suppliers. The EV Project provided all with the requirements for data collection and transmitting to the Blink Network, special data formatting for data analysis as well as the cost and schedule requirements of the EV Project. None provided a response with an existing product that complied with the requirements so ECOtality commenced the design, production and distribution of the EVSE.

It was intended that the EVSE would be utilized for many years following the completion of the project and be compatible with as many EVs as possible. The EVSE connector that plugs into the vehicle charge port inlet met the standard requirements of Society of Automotive Engineers (SAE) J1772 and other applicable EVSE and related standards.

The residential EVSE design provided an easy interface for EV owners and provided flexibility in the residence. The primary communications method was through the residence internet connection. The EVSE included additional features such as usage records and the owner obtained access to the data files maintained by the Blink Network at ECOtality through the secure member portal. Figure 7 shows the Blink residential EVSE.

Because the non-residential EVSE design was for utilization to continue for many years following the completion of the project, considerations for a sustainable business model including revenue collection were included. Debate over providing non-residential charging at no cost was intensive at the time and continues to this date. The EV Project strategized the initial stages of availability would be at no cost to the EV owner to assist in familiarizing the owner with the use and location of public charging. Access control introduction occurred at a later date followed by access fees. The sharing of utilization revenues with the charging site hosts provided additional incentives for adoption and hosting.

Figure 7: Blink Residential EVSE



Source: Blink Network

The project published the rationale for this time-based fee structure for public charging: *Electric Vehicle Public Charging – Time vs Energy*² (included as Appendix L).

This strategy required the EVSE design to include methods for access control, revenue collection, as well as the data collection and transmission. Communications systems that would be secure along with the low latency required for access control dictated internet or cellular communications. The human interface at the EVSE required ease of understanding and use as the EV owner had no prior experience with such equipment. Figure 8 shows an installation of the Blink non-residential AC Level 2 EVSE.

Figure 8: Blink Non-Residential AC Level 2 EVSE



Source: Blink Network

DCFC design required a different approach than the non-residential AC Level 2 EVSE. There was no SAE standard for fast charging available at the time. The Japanese CHAdeMO protocol was used in the design as that was used by the Nissan Leaf. Not all locations have access to 480-volt power. The highest voltage in some commercial areas is 208. Designing for 60 kW power then required 200-amp service for 208 volts or 89 amps for 480-volt service. The DCFC design included separate charge dispensing and power units accommodated both capabilities (a common dispenser for two different power units).

Because the DCFC converts the utility AC supply to DC for charging, it contains the conversion transformer and traditionally leads to a more industrial look. For several reasons, ECOTality

² [Electric Vehicle Public Charging- Time vs Energy](https://avt.inl.gov/sites/default/files/pdf/EVProj/106078-254667.tvse.pdf) <https://avt.inl.gov/sites/default/files/pdf/EVProj/106078-254667.tvse.pdf> [accessed April 6,2014]

elected to design the DCFC in two separate cabinets. The one containing the transformer (Grid Power Unit) could maintain the industrial look and would be located near the electrical service. The customer facing unit (Charge Dispense Unit) could then be more aesthetically pleasing and provide additional features such as the advertising display screen. Because users would remain near their PEV during charging, advertising on the 42" liquid crystal display screen provides an opportunity for revenue for the host and EVSE supplier to help offset costs.

Installation planning for AC Level 2 included at least two EVSE at each location for availability of charging and because installation costs for the second unit are considerably less. It is generally not practical to install two DCFC in the same location because of costs so the DCFC design included two charge ports. The high charge demand of two units simultaneously would again create electric supply issues, so the design incorporated sequential charging between charge ports. This design required greater user interface requirements so PEV owners completely understood the status of their charge or the wait period until their charge began.

The initial design anticipated the SAE would adopt the CHAdeMO standard for charging and did not anticipate the final SAE results of the J1772 "combo" connector. While the DCFC does provide two charge connectors, the difference in standards does not allow a simple exchange of one connector for the other.

The transformer included in the DCFC added considerable weight. The total weight of both components in the DCFC was nearly 2,000 pounds. Planning the distribution and installation of the DCFC required consideration of this significant attribute.

Figure 9 shows the Blink DCFC with the Charge Dispense Unit near the vehicle and the Grid Power Unit behind.

Figure 9: Blink DC Fast Charger



Source: Blink Network

Blink Network Planning

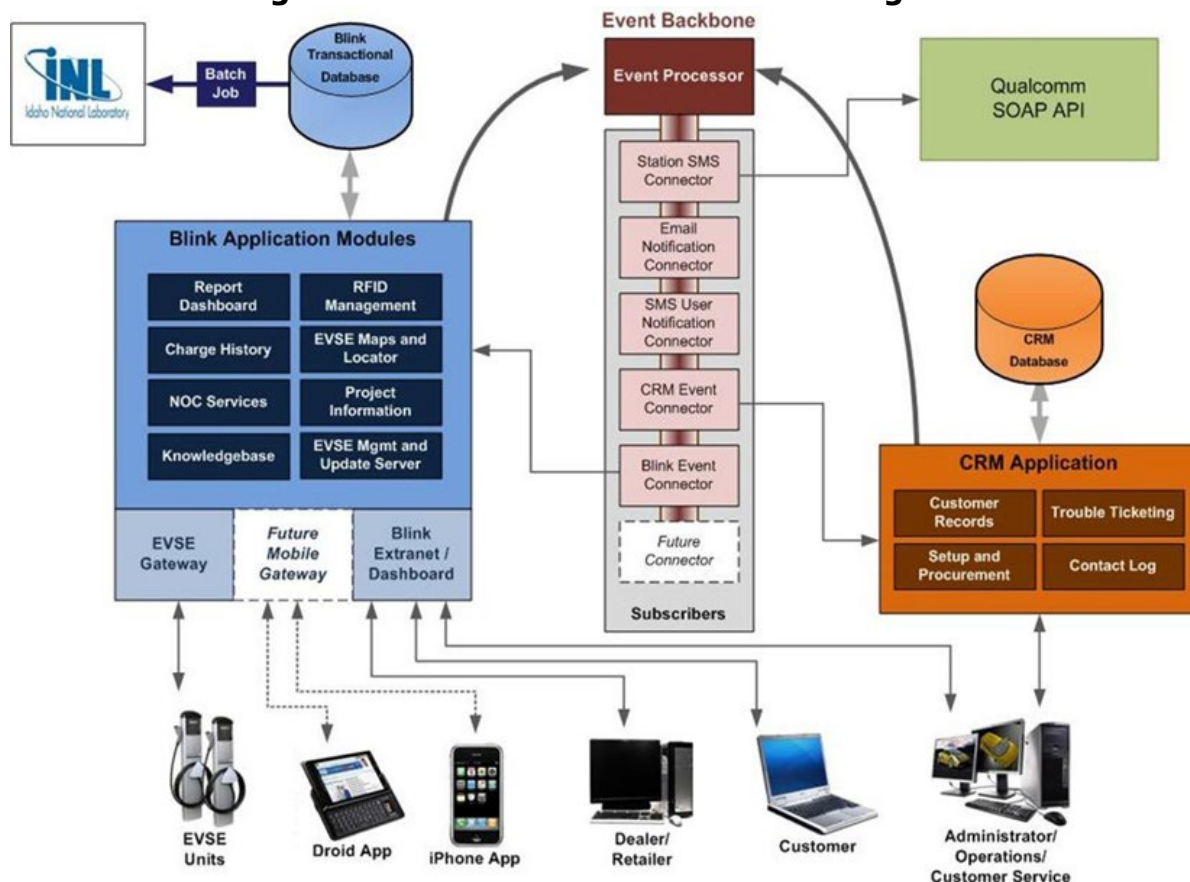
The Project activities required a system to receive and organize all data from the EVSE, provide for access control and revenue collection, provide user interface information and EVSE location mapping. This required the development of the website interface, back office administration, data collection systems, data warehousing and reporting. Curation systems included methods for verification that data is accurate, complete and timely. Data collection, transmission and reception errors are inherent in any system and the project had differing transmission systems for the EVSE and the vehicles. Figure 10 provides a functional diagram of the Blink Network developed to meet these functions.

Data Analysis Planning

Data analysis is a key element of the EV Project. The EV Project selected Idaho National Laboratory (INL) as a critical partner in this effort.

INL has conducted the DOE Vehicle Technology Program's Advanced Vehicle Testing Activity since the late 1980's when EVs were first tested. The Advanced Vehicle Testing Activity is singularly tasked by the DOE to demonstrate, test and collect data on emerging light-duty vehicle technologies as whole vehicle systems. INL's successful 20-plus year history of vehicle testing in field, test track, and laboratory environments, has two targeted audiences for its testing results: 1) DOE management, technology modelers, research and development programs, and vehicle and component manufacturers; and, 2) fleet managers and the general public, often the early adopters of advanced technology vehicles.

Figure 10: Blink Network Functional Diagram

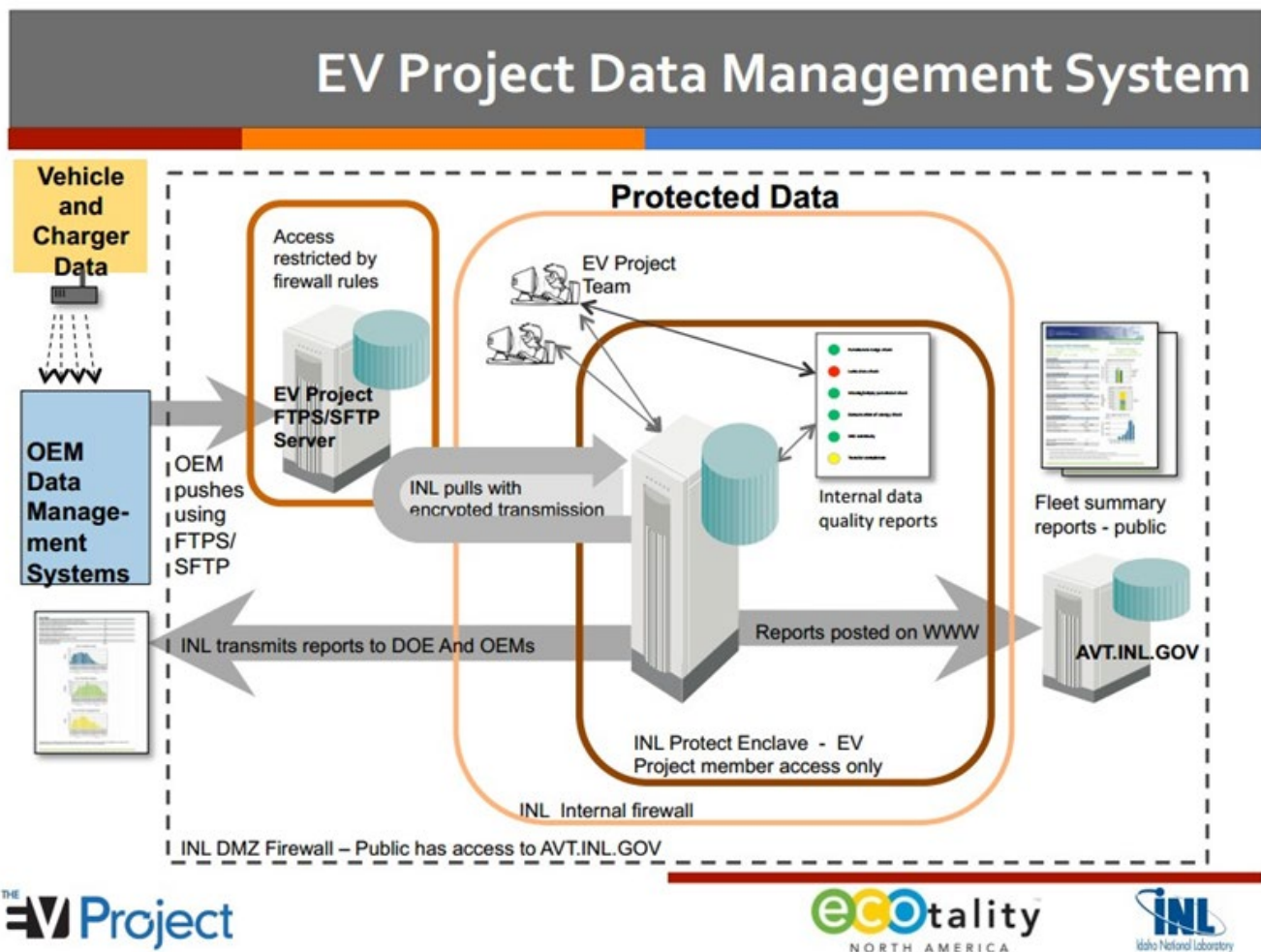


Source: Blink Network

INL receives data inputs from the Blink Network for EVSE data, from the Nissan Global Data Center for Nissan vehicle telematics information and OnStar for Chevrolet Volt vehicle telematics information. Appropriate contracts provided for individual data security and protection of personally identifiable information. Figure 11 identifies the INL data security and management system.

Through various analytical techniques, INL matches vehicle charge information from the vehicle telematics to the EVSE charge data from the Blink Network. This leads to the analysis presented publicly by the EV Project through published monthly reports, Lessons Learned and other public presentations and reports.

Figure 11: INL Data Management System



Source: EV Project

Deployment Planning

Manufacturing of the EVSE occurred in the U.S. and required inventory and distribution management to deploy to these several locations. The Project determined early on that local contractors provided the best resources for the installation of the residential and non-residential EVSE because they held the local licenses and knowledge required to expedite installation, and job creation was a major reason for the funding of this project. They were familiar with the AHJ as well as the local community. The deployment processes dictated the development of separate systems for residential installation and installations for non-

residential and different again for DCFC equipment. ECOtality provided the training for these contractors, certified their expertise, monitored and directed their projects. As noted previously, Chevrolet contracted with SPX to install all residential EVSE for Volt owners.

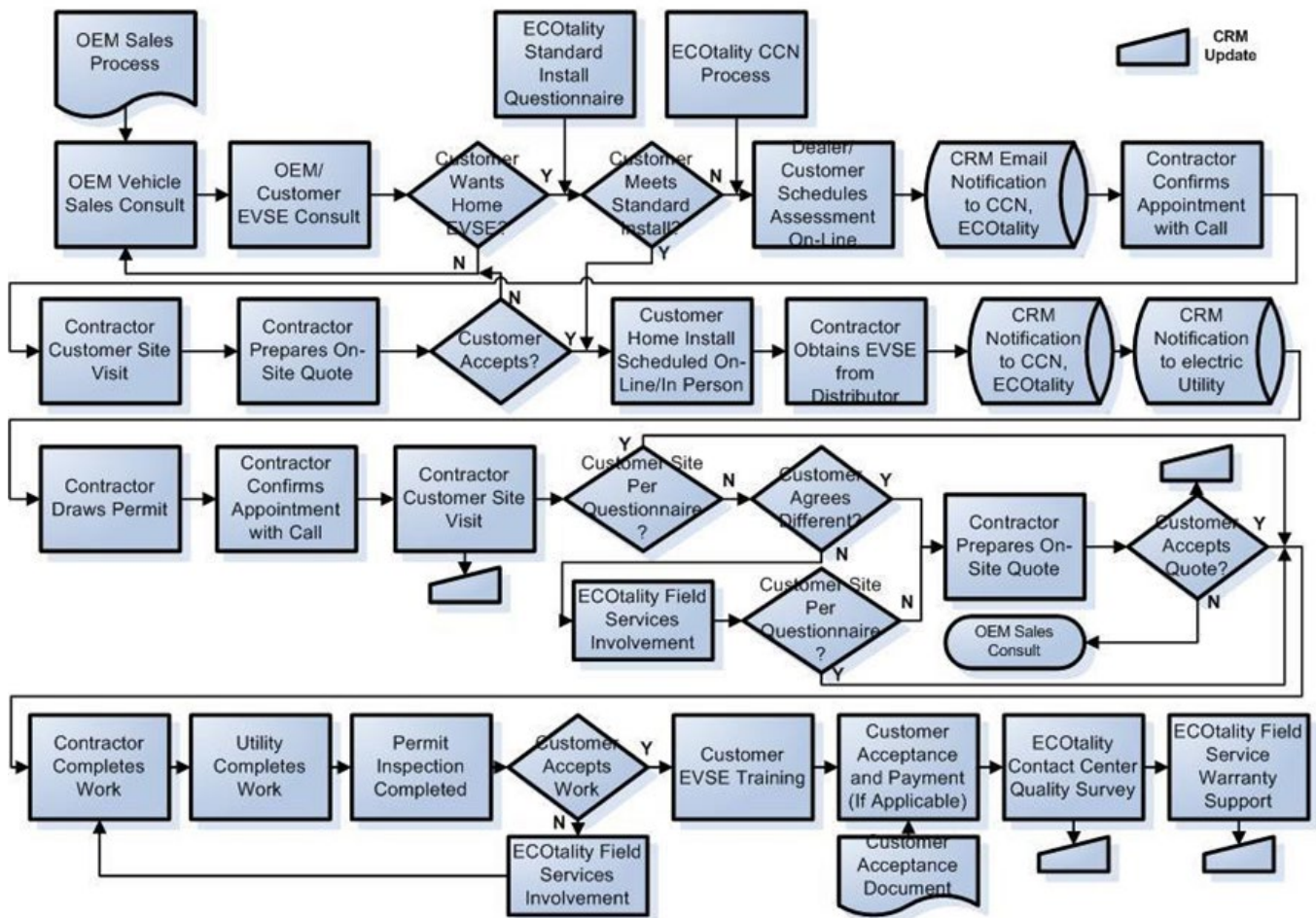
Residential Contractor Network Planning

A frequent complaint by homeowners involves the conduct of contractors from the building trades working in their home. Delays, inaccurate estimates, adding extra work, lack of promptness, and failure to leave the worksite in an acceptable condition are typical complaints. Nissan, Chevrolet and the EV Project determined to minimize any such complaints. Screening of the local contractors and establishment of project processes minimized the potential for these complaints.

Many contractor activities which modify the residence require local approvals and permitting. The AHJ processes require the contractor to submit the permit application, complete the work and obtain an approval through the AHJ's inspection of the project completion. The Project found that for a typical project installation, obtaining the permit required about 10 percent of the time and waiting for the inspection post completion required about 20 percent of the time. The EV Project expended considerable effort in working with all the local AHJs to streamline the permitting and inspection process. However, for many the installation of EVSE units were not included in existing permits, and consequently there was a wide variety of ways in which local authorities implemented their permit requirements.

Figure 12 identifies the typical residential EVSE installation process.

Typical EVSE Installation Process

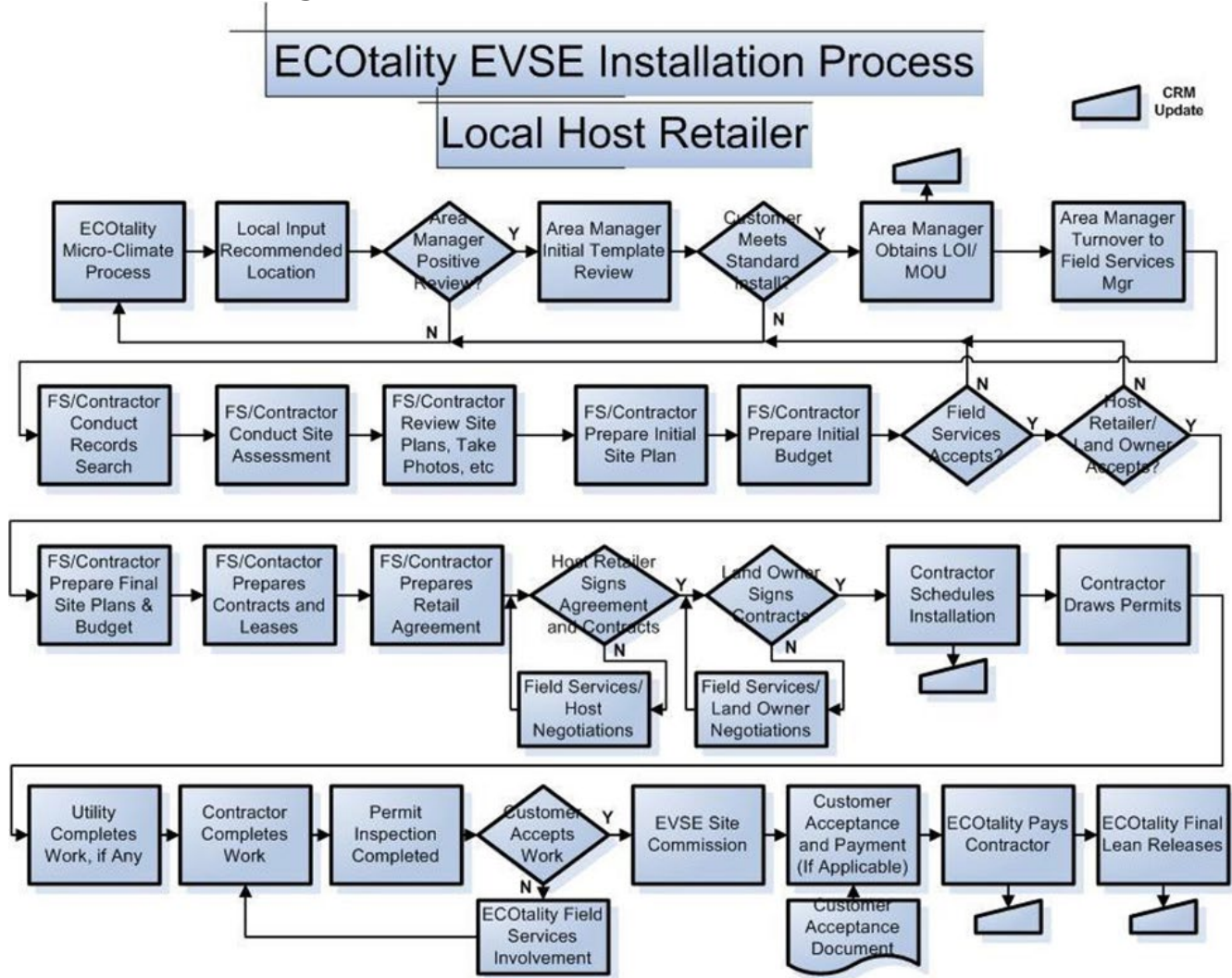


Source: Blink Network

Commercial Contractor Network Planning

As with the residential installations, contractor activities which modify the commercial property require local approvals and permitting. Here too, the AHJ processes require the contractor to submit the permit application, complete the work and obtain an approval through the AHJ's inspection of the project completion. Frequently, the commercial approvals required more extensive site planning which might include engineered drawings, architectural review and professional engineering approvals. The AHJ might require a plan check process which required additional time. The DCFC required even greater planning because of the complexity of design and higher power ratings of the equipment. Commissioning the non-residential EVSE required specialized training accomplished through the certification process. Figure 13 identifies the typical non-residential EVSE installation process.

Figure 13: Non-Residential Installation Process



Source: Blink Network

One of the most significant impacts to the charging site host in the installation of EVSE is the modification to the parking area requiring consideration of accessibility requirements of the Americans with Disabilities Act – 28 CFR Part 36 (ADA). Chapter 3 provides more information on this topic.

Chapter 3: Activities Performed

This Chapter reports on the activities performed under the agreement. Chapter 4 reports on the results of these activities. Activities required by this project included EVSE planning & documentation, EVSE deployment, data collection and conducting the special Smart Charging Demonstration.

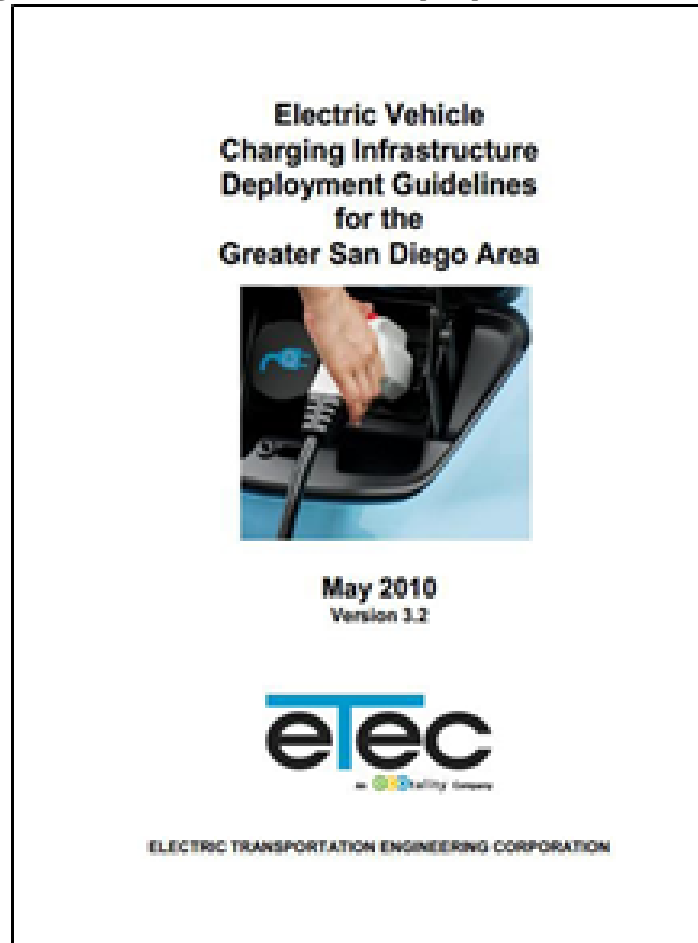
EVSE Planning Documentation

The EV Micro-Climate process provides three documents signifying the completion of the planning effort. They are the EV Charging Infrastructure Deployment Guidelines, the Long-Range Plan and the Micro-Climate plan. The San Diego Advisory Group was instrumental in the evaluation and completion of this effort.

EV Charging Infrastructure Deployment Guidelines for Greater San Diego Area

ECOTality prepared the draft Deployment Guidelines document for review and comment by the local Stakeholder Advisory Group. This document not only served to provide focus for the stakeholders in the process, but also provided the foundation for future work. It established a common language concerning PEVs and EVSEs, as well as the basics related to EVSE installation processes and considerations. Several local decisions are necessary for the successful deployment of EVSE, which then encourages further adoption of EVs in the community. The Advisory Group reviewed and provided comments on the draft guidelines to create the local version. It became a public document to which any additional stakeholders and enthusiasts could refer to understand the local deployment of electric vehicles and charging stations. Typical topics addressed in this document are general terms and nomenclature, EVSE descriptions, EV descriptions, charging scenarios, permitting, codes and standards, accessibility, point of sale, EVSE ownership and utility integration. The deployment guidelines document is shown in figure 14.

Figure 14: Infrastructure Deployment Guidelines



Source: EV Project

Long Range EV Charging Infrastructure Plan for Greater San Diego

The strategy of the EV Micro-Climate process was next to take the long view. By 2020, expectations are that there will be a variety of PEVs produced by many Original Equipment Manufacturers (OEMs) and current PEVs will be in their second or third owner so that PEVs appeal to all demographic groups. In addition, the adoption of PEVs spreads well beyond the major metropolitan areas to be generally available everywhere. The Long-Range plan investigates the introduction quantities of PEVs projected into the region and the infrastructure required to support them. These include those EVSEs in metropolitan areas and along the corridors that connect those areas. Some EVSEs will be range extenders to allow drivers, who live some distance from metropolitan areas, to access the local infrastructure grid.

ECOtality presented the Advisory Group a draft of the Long-Range Plan for review and comment. It was a starting point to develop the near-term strategy for infrastructure deployment of the EV Project and provide a basis for the direction of future deployment. Many Advisory Group participants were uncomfortable in addressing the deployment plans for the early adopters of EVs since demographically they represented a small segment of the population. The Long-Range Plan eliminates this specific demographic and views the community as a whole. It also identifies the surrounding community needs which may not be included in the specifics of the EV Project.

The Advisory Group then could evaluate the impact that PEV demand and local requirements play in determining whether a location would truly make sense as part of a complete EV ecosystem. The plan then considered local demographics, traffic patterns, AC Level 2 and DCFC distribution, EV consumer analysis, etc. to provide context for the plan. Resources of the Advisory Group (i.e. geographic information systems mapping capabilities, transportation data etc.) were provided in some markets to help execute this portion of the project. In essence, the plan represents the expected density of EVSE in the Greater San Diego area in the year 2020. Figure 15 originates in this document.

Figure 15: Level 2 EVSE Long-Range Plan Densities



Source: Blink Network

EV Micro-Climate Plan for San Diego Region

Following the completion of the Long-Range Plan, the EV Micro-Climate Plan was established. It identifies a shorter-term deployment strategy for the first few years of the Long-Range Plan in addition to immediate local opportunities which results in a specific location driven approach to PEV infrastructure deployment. Long-Range Plan projects the rate of PEV market penetration and the charging infrastructure needs to support that penetration in the very near future. Rather than blanket the area with infrastructure by simply finding agreeable hosts, this plan judiciously evaluated the demographics of the likely innovators and early adopters of EVs to establish a near term EV infrastructure. The main objective of this plan was to begin focusing on specific geographic locations that would identify the optimal placement of publicly available DCFCs and Level 2 EVSEs infrastructure in the Greater San Diego area and along local transportation corridors. Expectation is that a PEV driver willingly walks approximately 1/4 mile from an EV parking location to their desired destination. The goal then was to establish

target zones surrounding the major destinations and attractions within the specific market area as well as along the transportation corridors.

This document provides guidance for the Advisory Group and ECotality Regional Manager in the solicitation of charging site hosts. Figure 16 from this document provides ¼ mile targets for publicly accessible EVSE.

Figure 16: Potential Locations for Publicly Accessible Level 2 EVSE



Source: Blink Network

EVSE Deployment

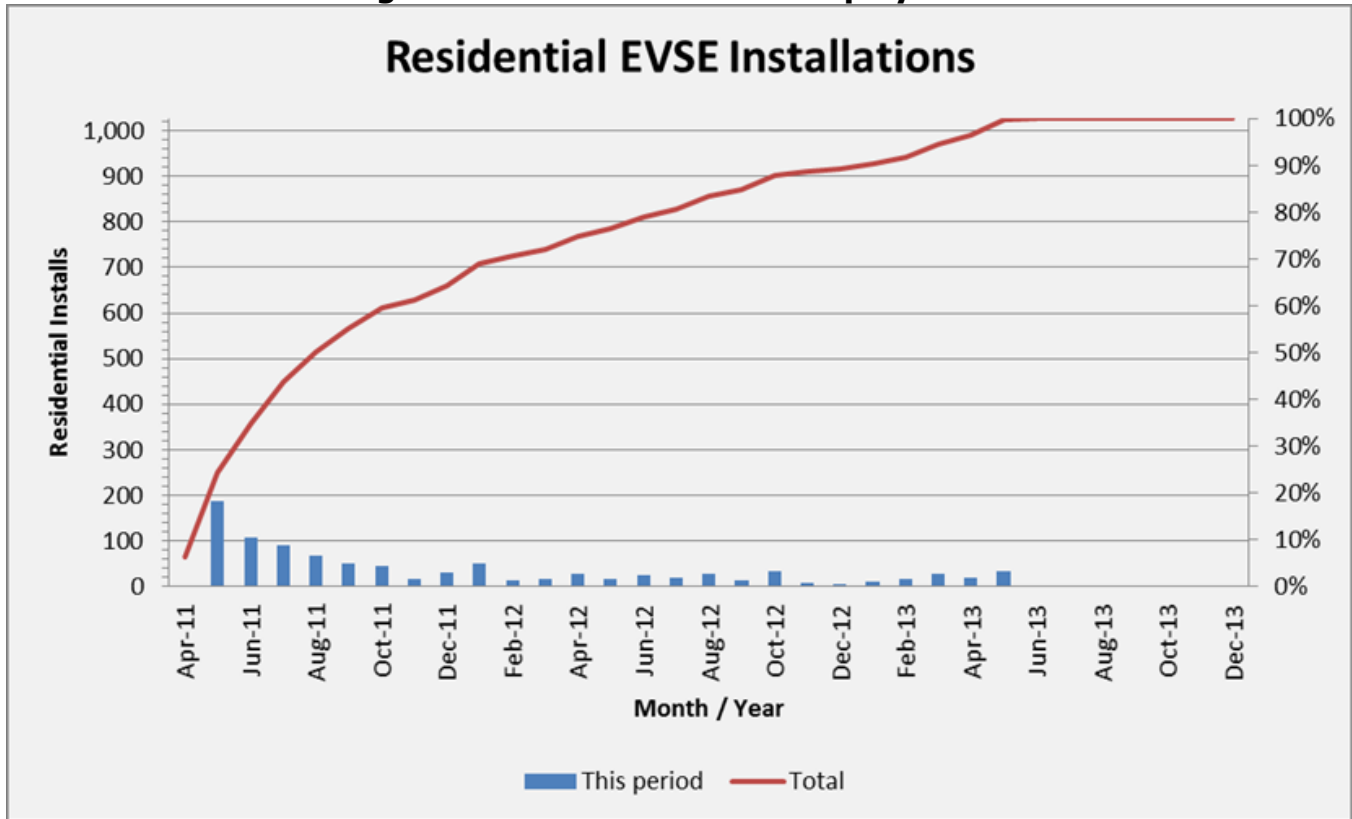
Deployment of EVSE followed the plan previously identified. Nissan and Chevrolet sales determined the quantity and rate of deployment of the residential EVSE. Production delays and less than anticipated sales in the original EV Project areas required the EV Project and DOE to agree to extend the project territories and project completion date. Commercial EVSE deployment commenced a few months after the deployment of residential EVSE. This was to encourage the charging site host with the availability of potential users. The sight of continuously unused EVSE is not conducive to either the sale of EVs nor of commercial EVSE.

Residential EVSE Deployment

In most cases for Nissan, the installation of the residential EVSE occurred a few days prior to the participant taking delivery of the vehicle. The installation of the EVSE for the Volt owner occurred within a few days after vehicle delivery. In both cases, the installation was not

complete until the closure of all permits following the inspection, the participant informed of the EVSE operation and the vehicle charged. The report of completed installation occurred after receipt of the contractor's invoice and all project documentation. Figure 17 shows the progression of residential installations.

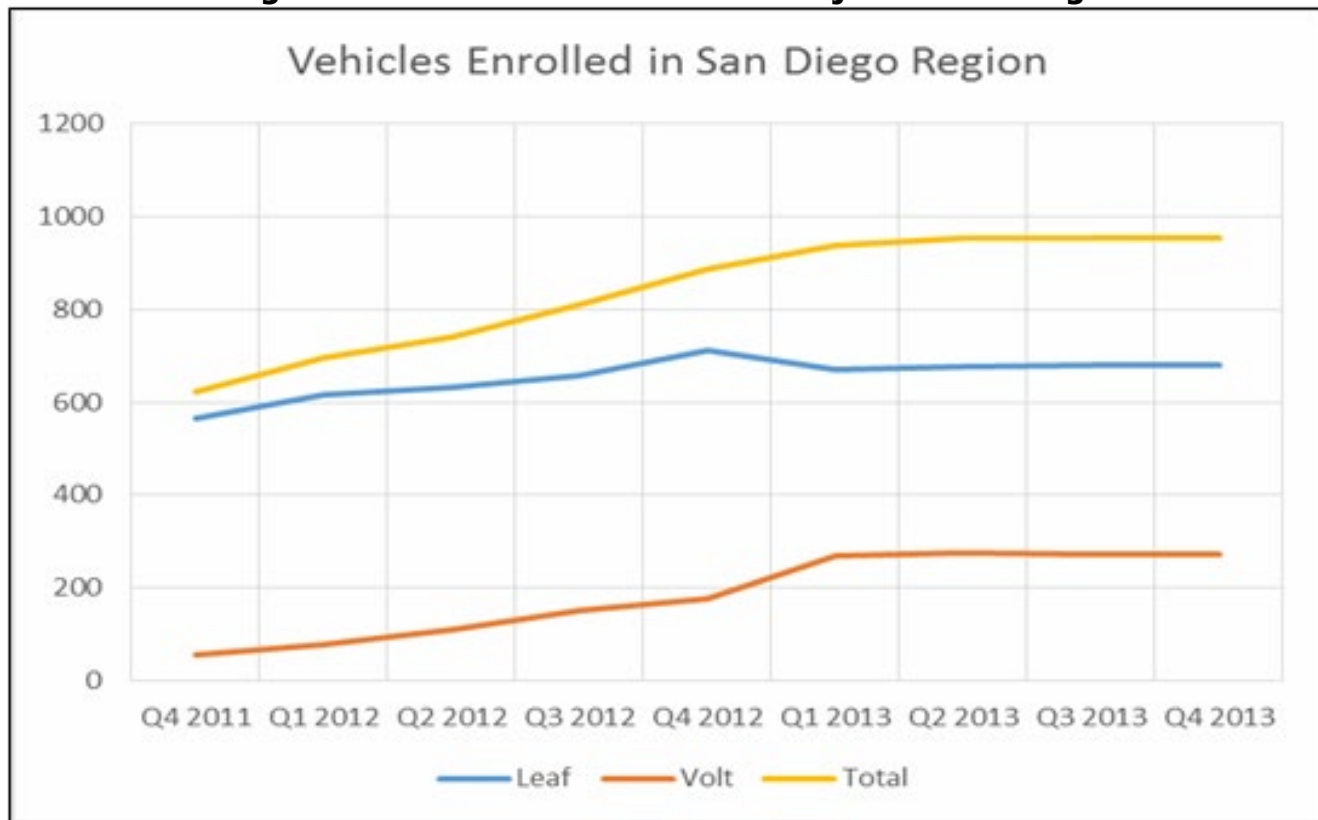
Figure 17: Residential EVSE Deployment



Source: Blink Network

Figure 18 displays the deployment of Leafs and Volts in the San Diego region by quarter since October 2011.

Figure 18: Vehicles Enrolled in EV Project in San Diego



Source: Blink Network

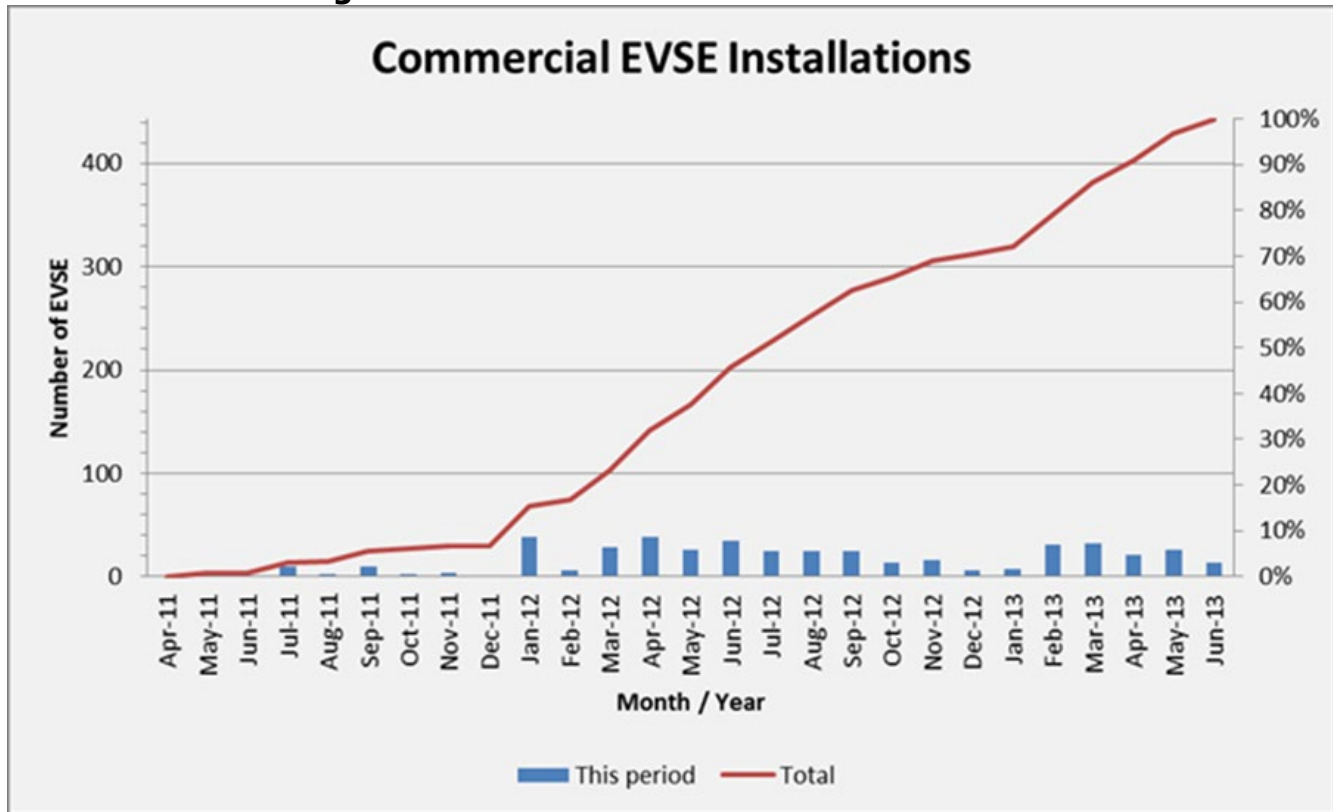
Non-Residential EVSE Deployment

Non-Residential EVSE include those accessible by the general public, those reserved for fleet use and those installed in workplace environments. The original intent of the infrastructure study was to focus primarily on publicly accessible EVSE, but high interest in workplace applications resulted in more deployments in these locations. This also opened the opportunity to study car sharing impacts as Car2Go began enrolling their SMART BEVs in the first quarter 2012.

The Car2Go concept is for members to find a car parked in their area, access it with their member card, drive to their desired location and leave it parked for someone else to access at that location. Electric cars used by Car2Go then typically use the public infrastructure and vehicles may be left at publicly accessible EVSE.

Figure 19 shows the installation progress of non-residential EVSE in San Diego.

Figure 19: Non-Residential EVSE Installations



Source: Blink Network

In San Diego County EVSE placed in publicly accessible spaces require compliance with ADA. No federal guidelines existed on compliance when AHJs began the review of the first public EVSE. Lacking any federal guidance, the five initial regions of the EV Project took up the question with their advisory groups. Most areas engaged local experts and AHJs as well as detailed study and evaluation by ECOTality. The EV Project published "Accessibility at Public EV Charging Locations" to provide guidance as a result of this effort. In California, the Division of the State Architect had prepared some initial requirement for state buildings in 2004 but these were applicable to state funded buildings facilities and universities only and did not address all the issues related to EVSE and DCFC installation.³ Appendix P provides this lessons learned document which is also discussed in greater detail in Chapter 5.

The California PEV Collaborative later published the *Accessibility and Signage for Plug-In Electric Vehicle Charging Infrastructure*⁴. These guidelines provided recommendations but did not address existing facilities where strict compliance would be prohibitively costly. The EV Project report provided such guidance based upon the original ADA requirements document.

The EV Project guidance included:

³ *Accessibility Guidelines for Electric Vehicle Charging Stations* 97-03

⁴ [Accessibility and Signage for Plug-In Electric Vehicle Charging Infrastructure](https://www.calbo.org/sites/main/files/file-attachments/ca_accessibility_for_ev_charging.pdf?1524861081)

https://www.calbo.org/sites/main/files/file-attachments/ca_accessibility_for_ev_charging.pdf?1524861081
[Accessed April 18, 2014]

In general, design requirements provided by the 2010 ADA Standards for Accessible Design can be accommodated in the design and installation of publicly available EVSEs. In some cases, strict interpretation of these design requirements may increase the project costs disproportionately or create such facility design issues that compliance is not feasible. Public policy and direction are favoring the expansion of the EV charging infrastructure and strict interpretation may impede its development. Consideration for this situation is already provided in the ADA Standards related to "disproportionality" and "maximum extent feasible".

For the purpose of the EV Project and early market deployment of commercial EVSEs, ECOTality finds that reasonable efforts to incorporate accessibility requirements during installation of its commercial DCFC stations can be accomplished under the above parameters.⁵

Notwithstanding the above allowances, some AHJs in project areas, including the San Diego area, required extremely strict compliance beyond that required by the ADA. In San Diego, compliance required an AC Level 2 EVSE to be installed wherever a DCFC was installed.

Publicly Accessible EVSE Deployment

The San Diego Advisory Group assisted the Area Manager in soliciting charging site hosts for the publicly accessible EVSE. High priority was given to the locations selected in the planning process. Each site required executing a separate contract which often involved the host, their management company, the property owner, and in some cases, the national headquarters. The significant amount of coordination required and the fact that the study had a limited amount of time to complete resulted in the search for the least expensive and easiest contracts. Time was short for the deployment of these EVSE. Liability insurance and maintenance concerns delayed or resulted in the host's declination of the EVSE. The host was responsible for costs above that allowed by the EV Project and compliance with ADA often times resulted in loss of the site.

While some host prospects were supportive of EVs, the lack of significant quantities and potential for unused EVSE was a concern. Chapter 4 reports on the results of the publicly accessible EVSE.

Fleet EVSE Deployment

Although the initial focus of the infrastructure study was for publicly accessible EVSE, fleet owners generated enough interest for the Project to expand eligibility. Thus, a limited quantity of the vehicles and publicly accessible EVSE destined for the San Diego area went into the fleet study. This included Car2Go which began deploying Smart EVs in the first quarter, 2012. The Car2Go fleet utilized their fleet EVSE and publicly accessible EVSE. Chapter 4 reports on the results of this deployment.

Workplace EVSE Deployment

Prior to the start of the project, some predictions suggested most recharging would occur at the residence followed by workplace charging. It was thought publicly accessible charging

⁵ [Accessibility and Signage for Plug-In Electric Vehicle Charging Infrastructure](https://www.calbo.org/sites/main/files/file-attachments/ca_accessibility_for_ev_charging.pdf?1524861081)
https://www.calbo.org/sites/main/files/file-attachments/ca_accessibility_for_ev_charging.pdf?1524861081
[accessed April 1, 2014]

would be the least used. However, not all shared these predictive views and in order not to limit the use of PEV's to commuter vehicles, publicly accessible charge infrastructure was often assumed vital to widespread adoption of PEVs. Some thought DCFC was unnecessary whereas others thought AC Level 2 in public would be unused. The importance of gathering data from actual use was thus validated. Workplace EVSE deployment requires considerable coordination and without widespread use of PEVs, most employers had little interest in considering incentives for employees related to PEV charging. Indeed, even years since the introduction of PEVs, this is a difficult issue for many. Tax implications for users, access control, location planning, installation costs, EVSE acquisition costs, AC Level 1 vs AC Level 2, favoritisms and other factors require extensive consideration. However, as with fleet EVSE, a significant interest from employers led to greater participation in the study than had been originally envisioned. Chapter 4 reports on the results of the workplace EVSE deployment.

DC Fast Charger Deployment

The deployment of DCFC followed a process similar to that for non-residential AC Level 2 EVSE. Greater coordination with SDG&E was required because of the higher electrical power requirements and frequent need to upgrade the electrical service to the site.

Five basic steps defined the DCFC process:

1. Design Phase: Site approval by ECOTality and site host, all agreements completed, and planning/permitting process initiated.
2. Permitting/Planning: Drawings and/or permitting review, which could include commission, city or town hearings.
3. Construction: Permits obtained and construction commencement.
4. Commission: Installation completion but waiting initialization.
5. Complete: Installation complete, site commissioned and DCFC activated.

The DCFC consisted of two primary units: grid power unit and charge dispenser unit. See Figure 20. The grid power unit received the power from the local utility service and transformed that to the DC power required for charging. The charge dispense unit could then receive that DC power in a more esthetically pleasing unit.

Figure 20: DCFC Installation



Source: Blink Network

EVSE Data Collection

The primary purpose of the project was to evaluate the use of charging infrastructure and the vehicles, therefore significant effort centered on the collection and analysis of data. The project took extreme care in exercising all the participant agreements, charging site host agreements, contractor agreements and contracts with Nissan, OnStar and Car2Go and other project partners to enable the collection of these data and to safeguard the privacy of participants. The project required new hardware and software systems for reporting, transmitting, receiving, storing, and warehousing these data. The reporting plan required new techniques for matching data from separate sources, i.e. charge event data from the EVSE to vehicle charge data from the OEM. Connecting databases between Nissan and the project to share participant prospect information and coordination of contractor actions required new techniques and extensive development. The normal life events of participants over the data collection period such as moving, divorce, death, foreclosures and project weariness required data monitoring vigilance. The EVSE required a core upgrade in first quarter 2012 to correct an early design issue involving data transmittal. Other data transmittal issues resulting from cellular dead zones or internet down time created suspect or missing data points that required further curation. Ultimately, the Blink Network and the INL databases became the data warehouses of accurate and verified data for the generation of reports and lessons

learned. The project accurately recorded over 4 million real-world charge events from these deployed EVSE.

The project planned to disseminate the information generated by these data by two means. INL's extensive history in data reporting provided the suggested content for a quarterly report. The project partners provided additional input to the format and content. The quarterly reports provide information on project statistics as the project developed. The Section below provides details of the content of these reports. The other means of reporting project information was publication of lessons learned and observations. Experience gained through the management of the project and through observation of gathered data provided the incentive to generate these documents. The project also hosted workshops with project partners and interested parties to solicit input for report topics. The EV Project website contains several lessons learned documents and project presentations as a result.

Data Methodology

A report on the data methodology employed in the project was previously submitted (Attachment G). The objective of this methodology was to identify, collect and analyze data from EVSE and from vehicles deployed in the EV Project in order to understand the charging behavior and habits of EV users. Data analysis was one of the goals of the project and the standardization of data communication, data sources and data type is the foundation of the Data Acquisition Methodology. Dynamic data collected in the project originates from three sources: the Blink EVSE utilizing the Blink Network, the Vehicle Telematics Systems for the Nissan Leaf and Chevrolet Volt, and manually through a monthly spreadsheet for Car2Go.

Privacy rules adopted by the project only allow the presentation of aggregated data from ten or more EVSE or vehicles. This prevents the identification of a specific EVSE or vehicle or person owning or using that equipment. If areas contain fewer than ten, the information is unreported. Thus, some regions may not display the particular information. For example, the published Infrastructure Report for 4th quarter 2013 Quarterly Report identifies four DCFC in the San Diego region. However, the report omits any detailed DCFC information.⁶

Transmittal of the final Data Methodology report occurred on July 2, 2013 and is referenced here.

Types of Data Collected

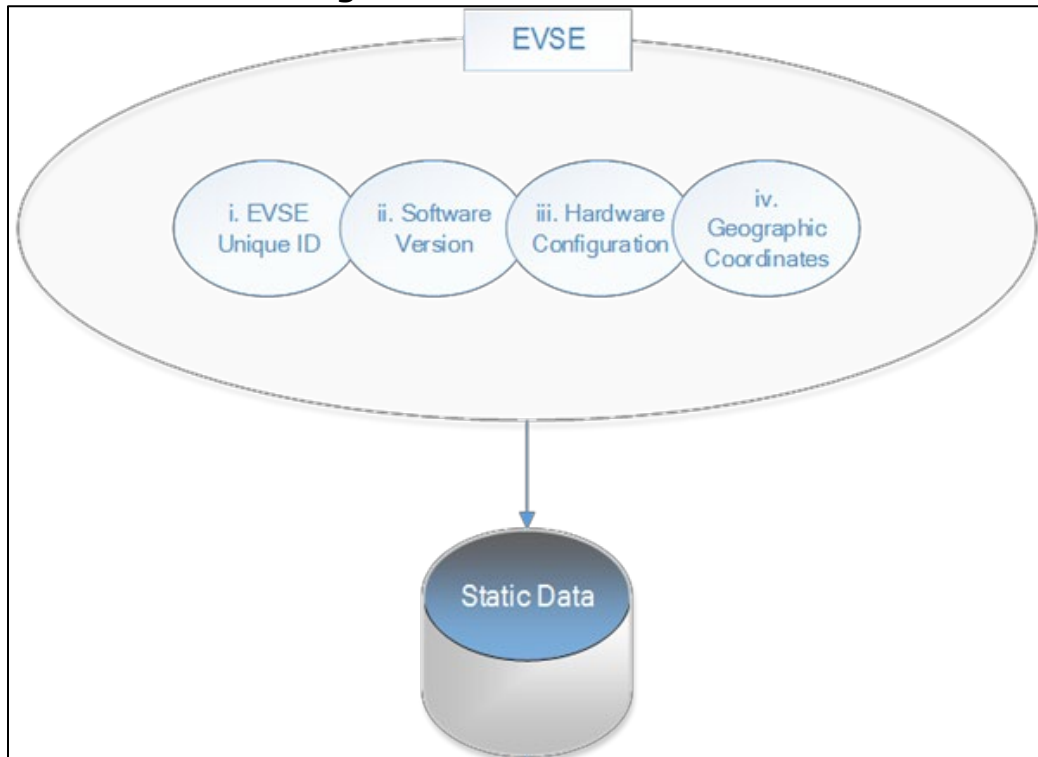
From each (General Motors, Nissan and Blink Network) both static and dynamic data are collected.

Static data are those that define and identify the vehicle and/or EVSE unit. They are constant even while the vehicle and EVSE unit create utilization data. Examples are vehicle identification number, EVSE identification number, EVSE location. Figure 21 shows an example of static data from the EVSE.

⁶ [EV Project Summary Report Q4 2013](https://avt.inl.gov/sites/default/files/pdf/EVProj/EVProjectChevroletVoltQ42013.pdf)

<https://avt.inl.gov/sites/default/files/pdf/EVProj/EVProjectChevroletVoltQ42013.pdf>

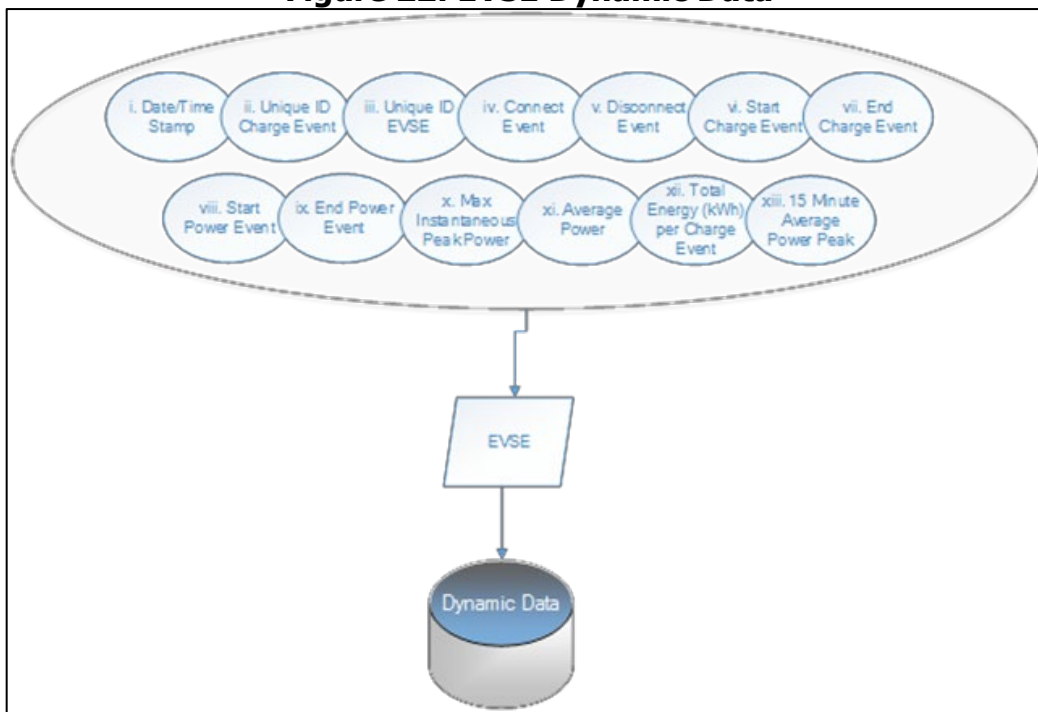
Figure 21: EVSE Static Data



Source: Blink Network

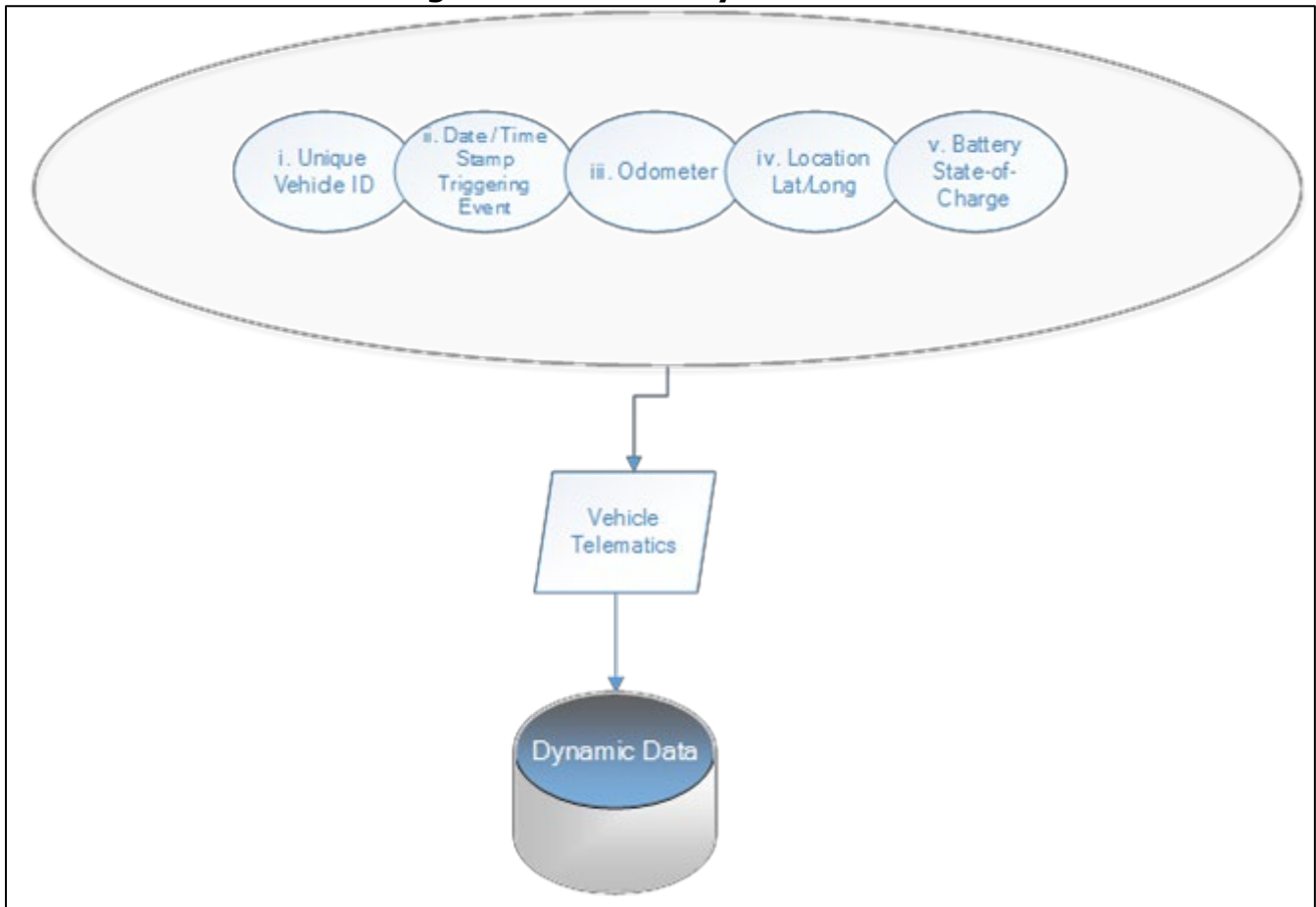
Dynamic data are those that change and indicate vehicle and/or charger use. Both the EVSE and vehicle's telematics systems provide dynamic data. Figure 22 illustrates some of the EVSE dynamic data and Figure 23 illustrates vehicle dynamic data.

Figure 22: EVSE Dynamic Data



Source: Blink Network

Figure 23: Vehicle Dynamic Data



Source: Blink Network

EVSE Data Collection

Successful data collection required the EVSE to successfully capture event data. As shown in Figure 22, a significant quantity of data required collection. Next, the EVSE must successfully connect and transmit the data to the Blink Network. The internet and cellular communications capabilities of the EVSE provided two methods for data transmittal. Approximately 95 percent of residential EVSE connected via the residential wireless internet connection. Likewise, approximately 95 percent of non-residential EVSE connected via cellular communications. In some cases, special provisions for connecting the EVSE to the network occurred through hardwired Ethernet cables.

The Blink Network received the incoming data and validated complete and accurate data. Data elements missing or incomplete transmittal required additional curation. The curation process identified the errors and corrected them, filled in valid missing information or eliminated the incomplete information. Valid data passed to the Blink Network database.

The EVSE design allowed vehicle charging in the event that connection to the Blink Network failed. Data cached in the EVSE transmitted at a later date when later connected. At times data transmittal occurred several weeks following actual charge information.

The Blink EVSE shipped from the supplier with an internal clock powered for a short time interval. It required updating from the Blink Network during the commissioning process. Some

contractors failed to complete this step in the commissioning process so initial data transmitted provided false time stamps. The design provided for the time update upon the first data transmittal so only the initial data transmittal was suspect.

The Blink Network transmitted EVSE data weekly to INL. Both the project and INL conducted data analytics on these data.

Residential Data Collection

The Residential Participation Agreement required the residential participant to own their residence, remain in the project for its duration and possess a wireless internet network for data transmittal. The residential EVSE remained the property of the project until successful completion of the Residential Participation Agreement terms. While owners of condominiums desired participation and owned their residence, approvals for EVSE installation required a more complex and time-consuming process involving the homeowners' association and others. Likewise, due to the complexity and variety of conditions for permitted installation of EVSE, the project excluded participation by apartment dwellers.

The initial volume of data revealed an issue in the AC Level 2 EVSE design that affected both the residential and non-residential units. EVSE data reporting was inconsistent and eventually traced to issues with the initial software design. Supplier issues with generic secure digital memory cards instead of those specified also contributed to initial data errors. Replacement of secure digital cards and a re-coding of the EVSE software core in early 2012 eliminated these issues.

Although designed for over-the-air software upgrades and such occurred during the project, the replacement of generic secure digital cards for the specified ones required hands-on replacement.

GPS positioning systems generate errors. The EVSE internal code division multiple access used for cellular communications also provided GPS position information. This was not generally used in residential applications and GPS position was geocoded by the residential street address. However, much of the data analytics required a match of the residential EVSE with the enrolled PEV. The GPS position reported by the PEV had its own inaccuracies.

Frequently, the GPS data from the vehicle did not match the geocoding of the residence. A buffer of 750 feet was established so that a vehicle charging within 750 feet of its associated residential EVSE was thus assumed to have charged there.

Misrepresentation by some participants resulted in inadequate network connection and successful data transmittal required extensive remedial methods. Some participants moved before the end of the project and removed the EVSE without notification to the project. Thus, data issues ensued when the same EVSE reported data from different locations. Some participants moved within the project boundaries, but some moved a considerable distance outside the boundary. As before the project encountered considerable effort to identify correct EVSE data. Some participants sold their home and left the EVSE behind while obtaining a new EVSE at the new residence. This resulted in the PEV being associated with two different EVSE. One participant experienced a residential foreclosure and the EVSE was included with the residence. A few residential participants disassembled the EVSE to reverse

engineer or revise the EVSE programming. Some participants terminated their wireless internet connection without notification.

Some of the residential usage reports required the matching of the residential charge information with the PEV charge information. Missing vehicle data or EVSE data then reduced the volume of this matched data. This was monitored by the project to identify which was missing and where attention was required to restore that information. The problem grew as the project neared completion because of the individual EVSE and the vehicle data issues.

Although creating significant work to correct the issues, the vast majority of participants honored their commitments and a significant volume of data was captured. Chapter 4 reports the results of the residential data collected.

Non-Residential Data Collection

The participant's execution of the Residential Participation Agreement also allowed the use of their charge data away from home. The charging site host's agreement provided for the transmittal of data for the duration of the project. The non-residential EVSE installation process required completion of the data communications capabilities between the EVSE and the Blink Network; typically, by cellular methods. GPS coordinates transmitted from the EVSE and on-site geocoding provided site identification for the EVSE. The EVSE design allowed over-the-air software updates and upgrades. The establishment of access control and access fees required these updates along with other typical software changes. While residential EVSE reported participant vehicle charge events at the participant's residence, non-residential EVSE reported charge events for all vehicles whether or not the owners were project participants. This distinction was important for some reports and INL developed techniques for matching participant vehicles to these charge events. EVSE placed in fleet and workplace environments required additional contract language to provide the charge data. In all cases, published reports only used aggregated data to protect the privacy of individuals. Chapter four provides the results of the non-residential the EVSE data.

As noted above, the AC Level 2 EVSE used an internal code division multiple access for data communications. It also provided GPS locations. The accuracy of location reporting varies with the code division multiple access design and the project had numerous issues with position information. The EVSE reported its position during data transmittal and that position information changed slightly based on satellite positions. Geocoding the position using the street address helped but also created issues with the location mapping program available to project participants and others. It was also uncovered that the geocoding information entered into the database could be subsequently overwritten by position information provided by the EVSE. Internal controls were required to identify the most appropriate location for the EVSE and to prevent overwriting that information. This location information was critical in matching the non-residential EVSE charge to the participant PEV position information to validate the pairing of the data.

The project's periodic reports identified all charging by the non-residential EVSE, including charge events with non-project vehicles. Thus, the failure to match project vehicles to these EVSE did not diminish the EVSE charge reports.

Vehicle Data Collection

Monthly General Motors, Nissan and Car2Go reported vehicle data. The process started with the project informing the OEMs of the participant vehicle enrolled in the project. This considered all new participants and those who exited or retired during the month. Nissan and General Motors send this information to their respective data centers to match the participant to the vehicle. INL received internet transmittal of data for vehicles thus identified. Car2Go provided a spreadsheet of monthly mileage data by vehicle directly to INL. At the same time, the project provided INL a list of the participants with corresponding same vehicle identifiers.

INL compared the lists provided by the OEMs and the project to report discrepancies. INL identified issues encountered to the project such as those identified below.

INL aggregated and organized the vehicle data to provide vehicle reports, infrastructure reports and project overview reports. In addition, INL and the project collaborated in providing lessons learned documents related to vehicle use.

Nissan Leaf

The project negotiated a contract with Nissan North America for providing the vehicle data for the project. The project transmitted the monthly participant list to the Nissan North America office in Tennessee. After processing, they forwarded it to the Nissan Global Data Center in Japan. As part of the Residential Participation Agreement, the participant was required to enroll in the CarWings program. This provided their approval for the collection and use of their vehicle data. Due to concerns over individual privacy, Nissan also required the participant's approval at every vehicle start via a touch screen response on their Leaf's navigation system. The vehicle cached the data to transmit daily upon initial start. Data transmittal was by cellular communications. The Global Data Center transmitted their monthly data directly to INL.

Nissan communicated prospects and assigned vehicles in advance of their delivery. Subsequently, some prospects declined delivery because of installation costs, loss of interest, production delays, etc. The vehicles thus delivered to the local dealer were then "orphaned" and available to others.

The DCFC charging feature was an option for this model Leaf and Nissan charged the project for the inlet costs.

In order to participate, Leaf drivers agreed to retain their vehicle and keep their overnight parking location within the project boundaries for the duration of the project.

Issues identified in the collection and analysis of the Nissan Leaf data included:

- Participant neglecting to enroll in CarWings or incorrectly submitting information
- Nissan incorrectly processing CarWings enrollment information
- Daily transmittal of data was from cellular "dead spot" so no data received
- Participants tired of tapping navigation screen to accept the transmittal of data on each vehicle start
- Mismatch between Participant and vehicle due to orphaned vehicles reassignment
- Participants moved without notification to the project
- Participants sold or transferred their vehicles without notification to the project

- Typical data transmittal and reception issues

Chevrolet Volt

The project negotiated a contract with Chevrolet and OnStar for vehicle data for the duration of the project. The project transmitted the monthly participant list to OnStar. OnStar then transmitted available data directly to INL. As part of the Residential Participation Agreement, the participant approved the data transmittal and agreed to enroll in the OnStar services. Vehicle data transmittal was by cellular communications to OnStar.

Chevrolet directed that SPX would conduct the installations of the residential EVSE. SPX was responsible for obtaining the participant's approval of the terms and conditions of the Residential Participation Agreement. The project transmitted participant lists only for those who executed the Residential Participation Agreement and its receipt by the project, the EVSE installation verified and the vehicle delivered.

Because the EVSE assignment occurred after the vehicle delivery, there were few issues related to miss-matches between vehicles and owners. Other issues, such as owners moving, participants' failure to enroll in OnStar, transferring vehicles and normal data issues remained.

Car2Go

The Smart for Two EV vehicle did not provide telematics so vehicle data transmittal occurred via manual reporting of the accumulated miles in the period. In order for this information to be useful, all charging had to be done via the Blink network of chargers using designated Blink cards that tied the energy delivered to the vehicle fleet. A monthly spreadsheet of vehicles enrolled, and odometer readings provided data directly to INL.

The Blink network provided Car2Go with Blink access cards for use by their customers. The project provided this list to INL for their analysis of charging conducted by the Car2Go vehicles. Blink Network usage cards paired with the individual Car2Go vehicles provided tracking of vehicles to the public EVSE utilized.

Data Reporting Process

The data collected was filtered, analyzed and ultimately used to create reports on the use of vehicles and charging infrastructure. [The EV Project website](https://www.energy.gov/eere/vehicles/avta-ev-project) (<https://www.energy.gov/eere/vehicles/avta-ev-project>) and the [INL website](http://avt.inl.gov/) (<http://avt.inl.gov/>) - Advanced Vehicle Testing Activity - provided public access to these reports. Since the first quarter of 2011, when Leaf and Volt vehicles and the residential EVSE were first deployed in the project (and in the USA), the quarterly report provides detailed information on the deployment status and utilization of vehicles and EVSE.

Publication of the Quarterly Reports occurs 30 days after the end of each quarter and contains five sections:

1. Introduction and Observations
2. Project Overview and summary
3. EVSE Infrastructure Report
4. Nissan Leaf report
5. Chevrolet Volt report

The Introduction and Observations section identifies significant events in the EV Project or important considerations, which might affect the interpretation of the information provided

and also provides commentary on changes, trends or comparisons between EV Project Regions.

The Project Overview provides a summary of the deployed charging units, charging events and the energy dispensed.

Because the vehicles provide information on their location during a charge and the EVSE provides its location, INL determines which EV Project vehicle has charged at which EV Project EVSE. The EV Project reports on all use by any PEV; even those that are not part of the project population. Likewise, the EV Project reported on all charging by the participating PEVs including charging by equipment that was not part of the study's deployed infrastructure (e.g. Level 1 charger provided with vehicle). This made the data more comprehensive, but also allowed further analysis of charging and driver behavior,

The Infrastructure Report provides detailed information from the EVSE perspective on utilization events and energy transferred. It contains an overview of all regions of The EV Project as well as specific regional reports.

The Nissan Leaf and Chevrolet Volt Reports provide detailed information from the vehicle's perspective. It provides an overview of all regions and specific regional reports.

Smart Charging Demonstration

In mid-2012 San Diego Gas and Electric (SDG&E) and ECOtality agreed to conduct a trial to evaluate how a "smart" charger could be used for demand response. ECOtality operated a large network of PEV charging units in the San Diego area, which included residential and non-residential AC Level 2 units.

SDG&E examined the possible criteria for the trial, including the use of tiered time-of-day pricing, various load shedding programs, and elected in the end to align this demonstration with their existing *Reduce Your Use* peak time rebate program.

Smart Charging Demonstration Process

Participants in SDG&E's Reduce Your Use Rewards program enables residential SDG&E customers to receive a rebate based upon their reduction in energy usage. The program is providing a "reward" when participants reduce their use during high usage hours on specified days –11AM-6PM and typically on very hot summer days.

The Smart PEV Charging demonstration targeted the *Reduce Your Use* program participants who also had a Blink residential EV charging station. The demonstration project worked as follows:

1. Reduce Your Use participants with Blink residential chargers were contacted and volunteers sought.
2. Those that volunteered to participate in the study would receive an email message about 24 hours ahead of an upcoming RYU event. The email would advise of the event time, date, and duration.
3. The participant then had the opportunity to opt-out of the event. This decision could be made at any time up to 15 minutes before the event.
4. By default, participants opted-in the demonstration and their Blink charge unit was disabled (via the Blink Network server) during the Reduce Your Use event.

5. Once the peak power period starts the Blink charging unit is disabled for trial participants that have not opted-out. However, there is an override button on the screen to permit charging in an emergency.
6. At the conclusion of the peak power period EV charging is once again enabled and a summary of the participant behavior is recorded.

Networked EVSE Technology

The demonstration requires the following technological requirements:

1. The ability for SDG&E personnel to schedule the Reduce Your Use program events.
2. Signaling of the Reduce Your Use program events to Smart EV Charging trial participants via email and the collection of the opt-out responses
3. The control of Blink residential EVSE to disable charging during the peak power period.
4. Permit emergency override of a disabled Blink EVSE unit.
5. The collection and reporting of user behavior data during the peak power period including the number of trial participant that elect to opt-out.
6. In order to meet the requirements outlined above the following technical modifications were developed and demonstrated:
7. SDG&E's utilized a software platform from Candi Systems in order to provide a user interface for Reduce Your Use events. The definition of events included the specification of the EVSE group and the of start/end times.
8. The Blink Network received the Reduce Your Use event details via a web services API.
9. The Blink Network issued a message to participating EVSE owners via email specifying the timing of the Reduce Your Use event and presenting an Opt-out option.
10. At the prescribed date and time of the Reduce Your Use event the Blink Network commanded the EVSE to disable charging for the configured duration.
11. The Blink EVSE displayed a message on the local user interface (screen) specify that charging was disabled due to a Reduce Your Use event. The user was presented a button on the screen to allow for an emergency override and re-enable charging.
12. At the conclusion of the Reduce Your Use event, the Blink Network issued a summary report to the SDG&E Candi system, listing the timing of the event, the number of participant and the number of users that opted out. The Candi system added additional event info and issued an event report.

Reporting from the Smart Charging Demonstration

In the summer of 2013, multiple Smart EV Charging demonstrations were linked to the Reduce Your Use program. The final event occurred on September 23rd, 2013. The reports below show sample results of that trial event. Tables 1 and 2 detail the event at the point of schedule and includes the email communications text and the group (in this case residential).

Table 1: Candi Event Details

Event Name	RYU Test 9-22-2013
Start	2013-09-23 11:00 (PDT)
End	2013-09-23 13:00 (PDT)
Type	Pending
Process Status	New
Last Detail Updated	2013-09-22 16:26:31 (PDT)

Source: Blink Network

Table 2: Partner Event Details

Price	0.00
Communication Text	Test Event for Reduce Your Use. Testing is from 11:00 am to 1:00pm Monday 9/22/2013. You will not earn Reduce Your Use rewards during this test event.
Group	RESIDENTIAL

Source: Blink Network

Tables 3 and 4 are issued at the start of the Reduce Your Use event and includes the number of participants and any that opted out.

Table 3: Candi Event Details with Participant Numbers

Event Name	RYU Test 9-22-2013
Start	2013-09-23 11:00 (PDT)
End	2013-09-23 13:00 (PDT)
Type	Active
Process Status	Update Done
Last Detail Updated	2013-09-23 09:13:16 (PDT)

Source: Blink Network

Table 4: Partner Event Details with Participant Numbers

Event ID	1979762121
Start	2013-09-23 11:00:00 (PDT)
End	2013-09-23 13:00:00 (PDT)
Modified	2013-09-23 16:26:25 (PDT)
Price	0
Communication Text	Test Event for Reduce Your Use. Testing is from 11:00 am to 1:00 pm Monday 9/22/2013. You will not earn Reduce Your Use rewards during this test event.
Group	Residential
Event Total Count	12
Event Opt Out Count	0
Event Scheduled Count	12
Event Cancel Count	12
State	STARTED

Source: Blink Network

Finally, tables 5 and 6 are generated at the conclusion of the event.

Table 5: Candi Event Conclusion Details

Event Name	RYU Test 9-23-2013
Start	2013-09-23 11:00 (PDT)
End	2013-09-23 13:00 (PDT)
Type	Completed
Process Status	Update Done
Last Detail Updated	2013-09-23 16:45:19 (PDT)

Source: Blink Network

Table 6: Partner Event Conclusion Details

Event ID	1979762121
Start	2013-09-23 11:00:00 (PDT)
End	2013-09-23 13:00:00 (PDT)
Modified	2013-09-23 16:45:19 (PDT)
Price	0
Communication Text	Test Event for Reduce Your Use. Testing is from 11:00 am to 1:00 pm Monday 9/23/2013. You will not earn Reduce Your Use rewards during this test event.
Group	RESIDENTIAL
Event Total Count	12
Event Opt Out Count	0
Event Scheduled Count	12
Event Cancel Count	0
State	ENDED

Source: Blink Network

Conclusion of Smart Charging Demonstration

The demonstration conducted by the Blink network and SDG&E's Reduce Your Use Rewards program was successful. It demonstrated the technical viability of scheduled, remote control of EV charging. The demonstration clearly showed the benefits of internet connectivity of EVSE and the value of a full featured, interconnected server-based control logic.

Though limited in scope, it also showed a willingness on the part of EV owners to participate in time of day energy reduction programs, with a 100 percent opt-in rate for all events.

Chapter 4: Results

As the first large-scale national deployment and study of PEV and charging infrastructure, the EV Project accumulated a number of accomplishments at the national level, including:

- Deployed 8,251 residential AC Level 2 EVSE units
- Deployed 4,005 public AC Level 2 EVSE units
- Deployed 107 DCFC Chargers
- Collected data on 4,173,933 Charging Events
- Collected data from 5,788 Nissan Leafs
- Collected data from 2,024 Chevrolet Volts
- 416 Car2Go vehicles participating
- 124 million test miles accumulated on project vehicles

Collected and transmitted to INL utilization data from 20,591 discrete sources of data

Through 2013, the deployment of chargers and vehicles in San Diego and Orange Counties included:

- Deployed 1,026 residential AC Level 2 EVSE
- Deployed 552 public AC Level 2 EVSE
- Deployed 7 DCFC
- Collected data on 633,063 Charging Events
- Collected data from 681 Nissan Leafs
- Collected data from 272 Chevrolet Volts
- 386 Car2Go vehicles participating
- 19,598,336 test miles accumulated on project vehicles

Collected and transmitted to INL utilization data from 2,899 discrete sources of data

Planning Results

Chapter 3 reported the completion of the three major planning documents for the deployment of non-residential EVSE in the San Diego region. The EV Micro-Climate® Planning Process⁷ lessons learned document, posted to the project website, reports lessons learned during the planning process. Appendix Q provides this lesson learned document. The major conclusions that can be drawn from this assessment are:

Stakeholder Advisory Group: Unification of the group is essential. Each member of the group has his/her own motivation and focus for the deployment of EVSE that has the potential for conflict. This was not the case in San Diego. Overall, the group was very productive and supportive of the process.

⁷ [The EV Micro-Climate Planning Process Lessons Learned](https://avt.inl.gov/sites/default/files/pdf/EVProj/EVMicroClimatePlanningProcessV1.0.pdf)

<https://avt.inl.gov/sites/default/files/pdf/EVProj/EVMicroClimatePlanningProcessV1.0.pdf> [accessed April 5, 2014]

Draft Documents: Providing draft documents for the group to edit was very beneficial to jump starting the discussions. Each area modified the documents for their purposes and region.

Common Issues: Issues common to all regions of the project included signage, ADA compliance, terminology, clustering potential required discussion by the group. Knowledge of what other regions considered fostered synergistic solutions. A common approach to signage and ADA resulted.

Geographic information systems mapping: Some regions excelled in the use of geographic information systems mapping for location planning. The San Diego group was especially effective.

Motivation Assessment: It was important to allow all group members to identify their highest motivation in location planning. Various motivations existed which needed to be understood by all.

Charging Site Host motivation: While the group united around the final plan, the sites still needed acceptance by the local host. Their acceptance of the EVSE, even with the significant incentives was not an easy task.

The overall planning process was an eight to nine-month effort. This did not add time or cost to The Project because it coincided with the development of charging hardware that met the project's needs and was ahead of vehicle availability. The final EV MICRO-CLIMATE® planning phase completion occurred just prior to the availability of the first Nissan LEAF vehicles. This also preceded the delivery and installation of the first publicly available EVSE by approximately six months.

Deployment Results

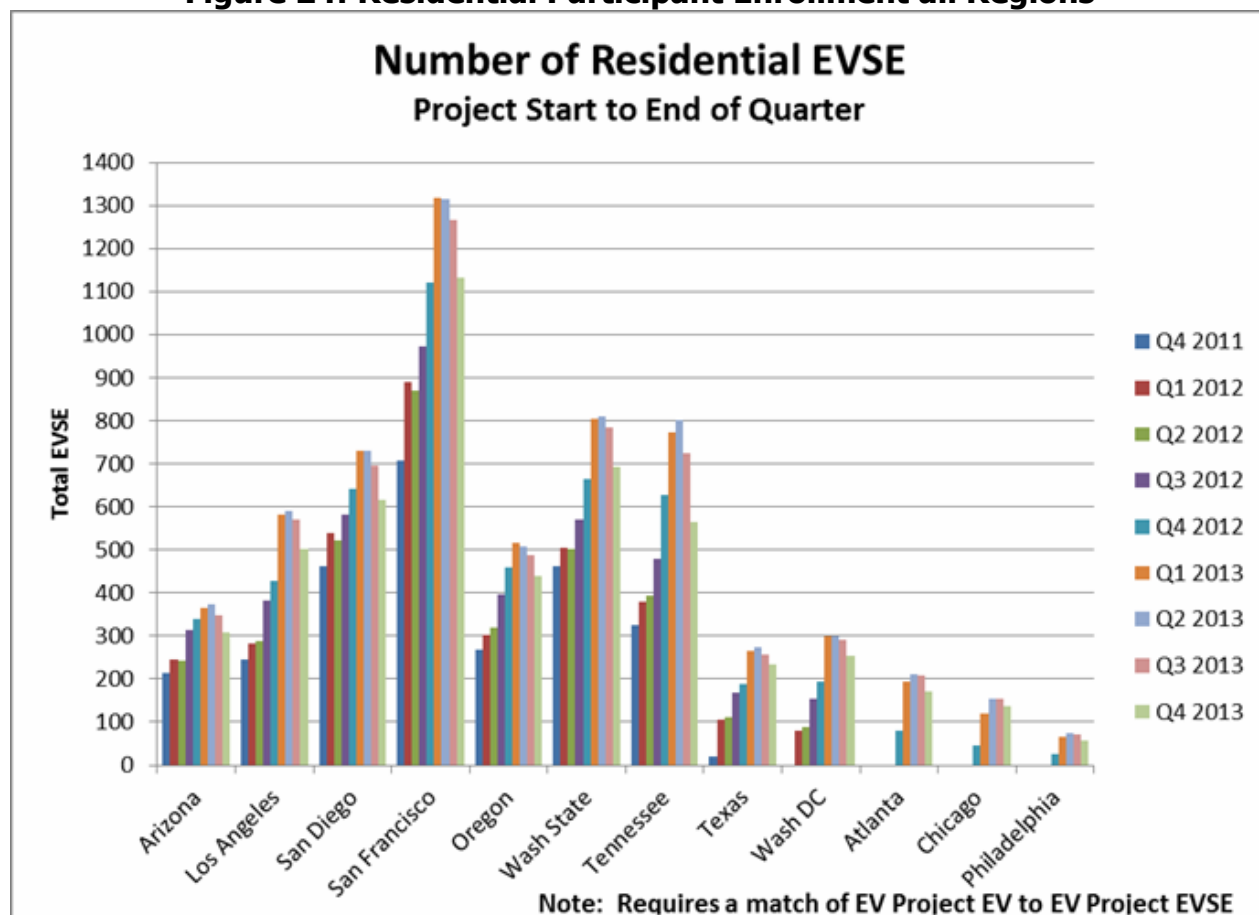
For the purposes of this report, the final deployment quantities in the San Diego and Orange Counties included 1026 residential EVSE, 552 non-residential AC Level 2 EVSE and 7 DCFC were installed prior to December 31, 2013. In addition to the 953 Leaf and Volt vehicles, 386 Car2Go SmartForTwo EVs participated in the project. Figures 17 and 19 show the respective deployment timelines.

Residential EVSE Deployment Results

This project included 962 residential EVSE units. However, the deployment phase of the EV Project provided 64 residential units ahead of the execution of the effective date of this award for a total of 1,026 residential EVSE deployed. The specific locations are personally identifiable information and are not disclosed in any public document, but Appendix B provides a count by zip codes.

The San Diego region had high participant enrollment compared to all regions in the project. Figure 24 provides the residential deployment history of each region in the EV Project for comparison. The EV Project quarterly reports Infrastructure section provide the data points for this figure. Note that a criterion for this Infrastructure report is that both the vehicle and the EVSE reported data in the quarter so that a match of the two is possible. As a result, the maximum number of matching data in San Diego was 731 units.

Figure 24: Residential Participant Enrollment all Regions



Source Blink Network

Note that the decline in the number of residential EVSE is due to retiring participants and lack of matching EVSE to vehicle data in the last two quarters of 2013.

Although some regions of the EV Project fell short of their residential participation objectives overall, the project was successful in meeting its goals for enrollment. The project closed enrollment early in the first quarter of 2013 and limited new participants to those whose installation was in progress.

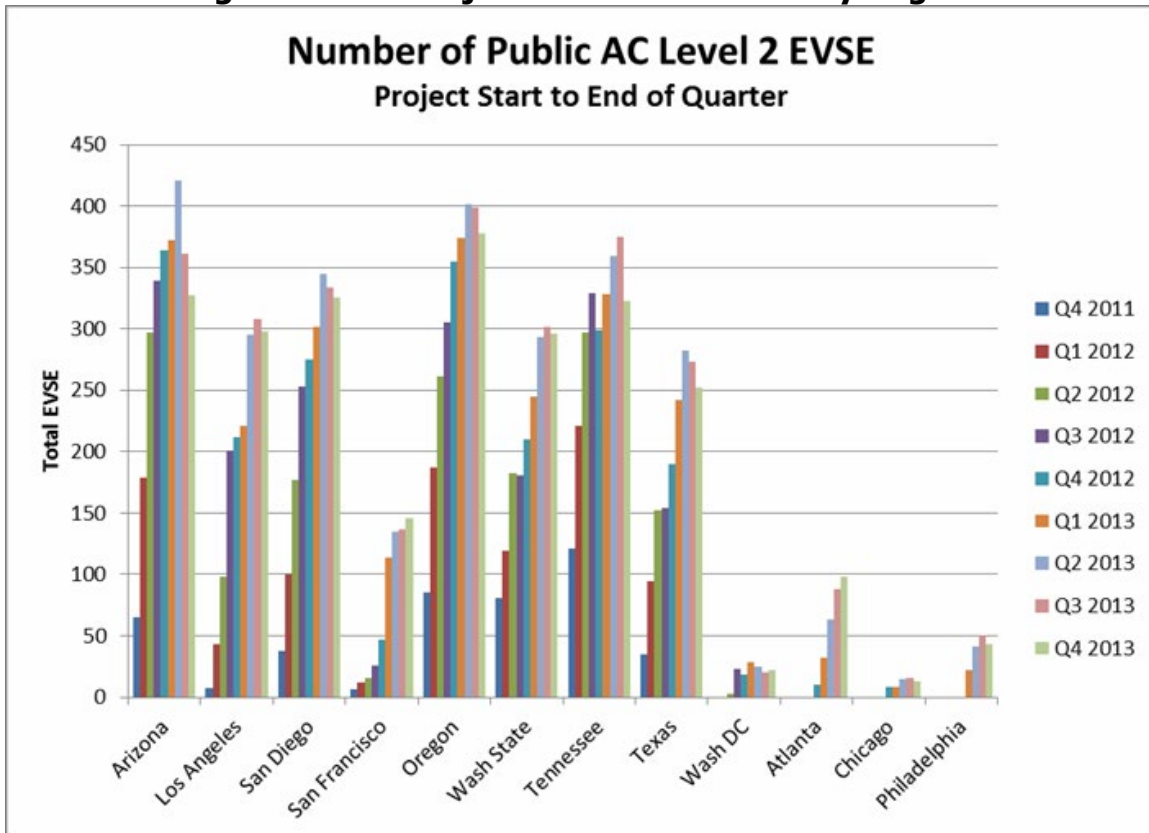
Non-Residential EVSE Deployment Results

The deployment of non-residential EVSE largely followed the plan prepared by the Advisory group. Some deviation from the intended publicly accessible EVSE to workplace and fleet applications occurred. (Section 4.4.1 provides an evaluation of the deployment process.) While this project funded 443 non-residential EVSE, there were a total of 552 non-residential EVSE deployed and evaluated in the project area through June 2013 at the time of the last monthly report to CEC. These included publicly accessible, fleet and workplace EVSE.

Figure 25 shows the deployment of publicly accessible AC Level 2 EVSE across the several regions of the project. Note that until the fourth quarter 2012, the public EVSE figures included fleet and workplace applications. Separate analysis of these fleet and workplace EVSE units started in the fourth quarter 2012. This figure shows the enthusiastic acceptance by charging site hosts in the San Diego region. The region also excelled in the deployment of

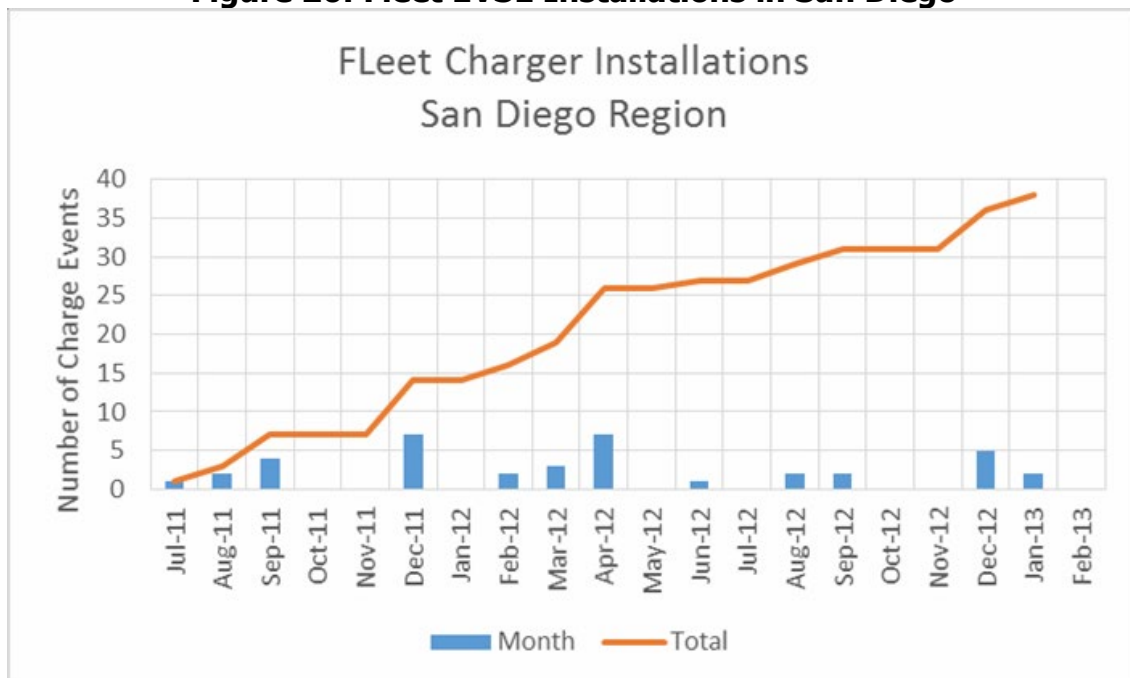
fleet and workplace installations. The decline in EVSE in the last two quarters of 2013 is likely a result from the bankruptcy influence on unit use and servicing.

Figure 25: EV Project Public AC Level 2 by Region



Source: Blink Network

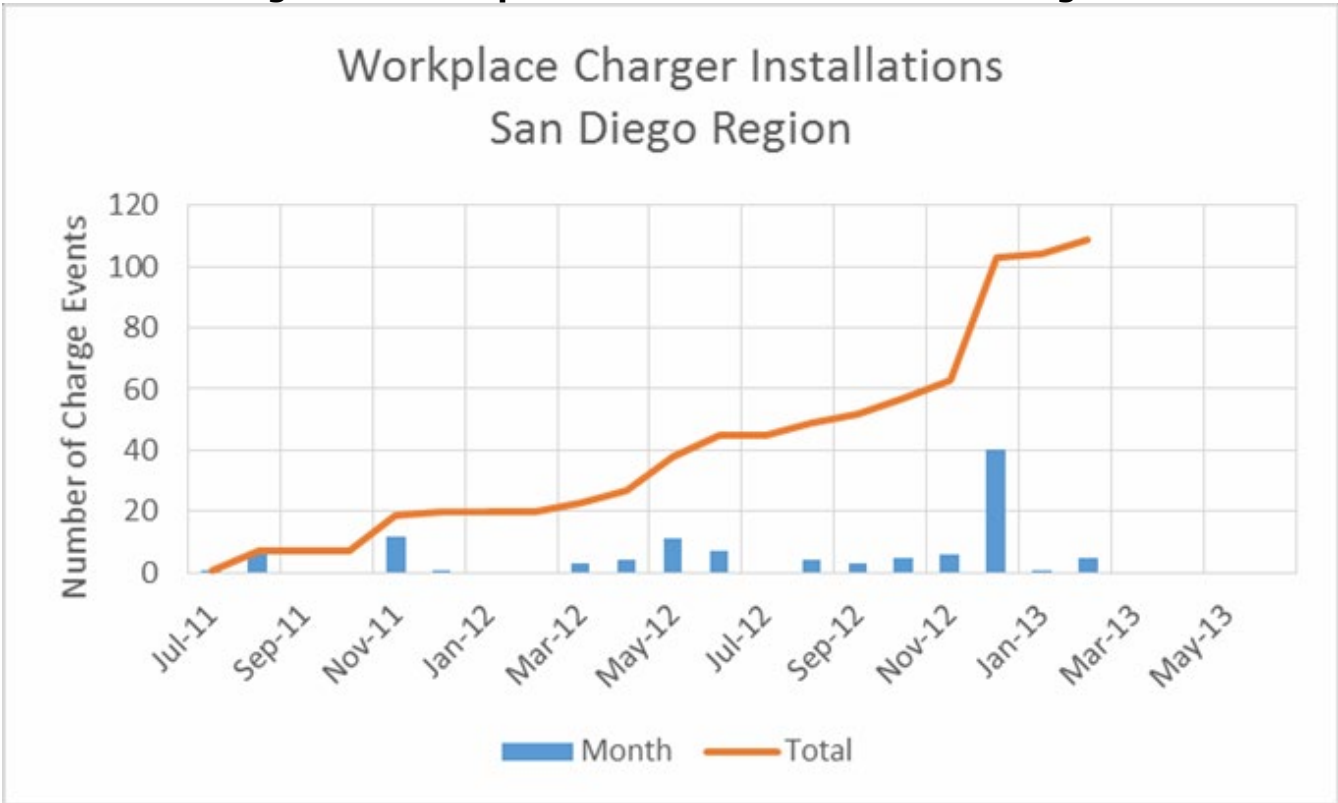
Figure 26: Fleet EVSE Installations in San Diego



Source: Blink Network

Figure 27 shows their installation timeline.

Figure 27: Workplace EVSE Installations in San Diego



Source: Blink Network

DC Fast Charger Deployment

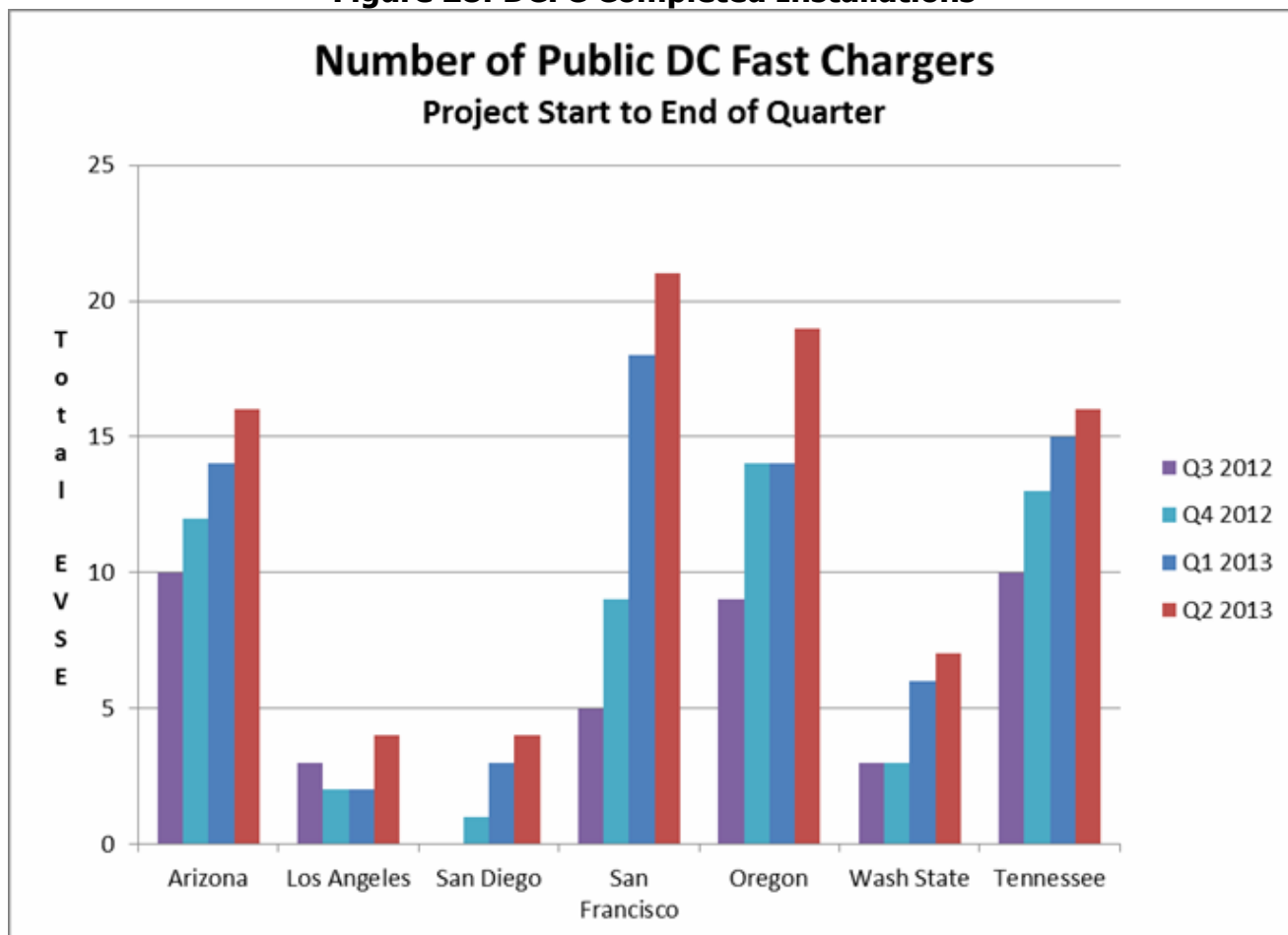
The Micro-Climate plan addressed the deployment of DCFC as well as the non-residential EVSE. However, it was much more difficult to secure host sites for the DCFC. In addition to the cost of the installation, there was often electrical service upgrades required, and the operating costs affected by the electric utility’s “demand charges” provided further hindrance for acceptance.

Demand charges are charges levied by the utility for the peak power used during a billing cycle, regardless of the amount of energy drawn at this power rate. These demand charges can add significantly to the utility bill for an EVSE host and can even make EVSE hosting cost prohibitive. While demand charges could also apply for the AC Level 2 EVSE hosts, the DCFC hosts’ demand charge costs are certain and are likely to be more significant because of the much higher power draw by a DCFC. The EV Project published a lessons learned document: *DC Fast Charge – Demand Charge Reduction*⁸ (Appendix R) which addresses this issue and discusses opportunities for demand charge avoidance. The purpose of the Smart Charging Demonstration discussed in Section 3.5 was to demonstrate one method of using an EV charging network to mitigate demand and therefore demand charges.

⁸ [DC Fast Charge- Demand Charge Reduction](https://avt.inl.gov/sites/default/files/pdf/EVProj/DCFCDemandChargeReductionPart2.pdf)
<https://avt.inl.gov/sites/default/files/pdf/EVProj/DCFCDemandChargeReductionPart2.pdf> [accessed April 6, 2014]

By June 2013, the project completed four DCFC installations in the San Diego region. The project also reported a total of 107 DCFC installations throughout all regions. Figure 28 illustrates the history and comparisons of DCFC in all regions.

Figure 28: DCFC Completed Installations



Source: Blink Network

Data Collection Results

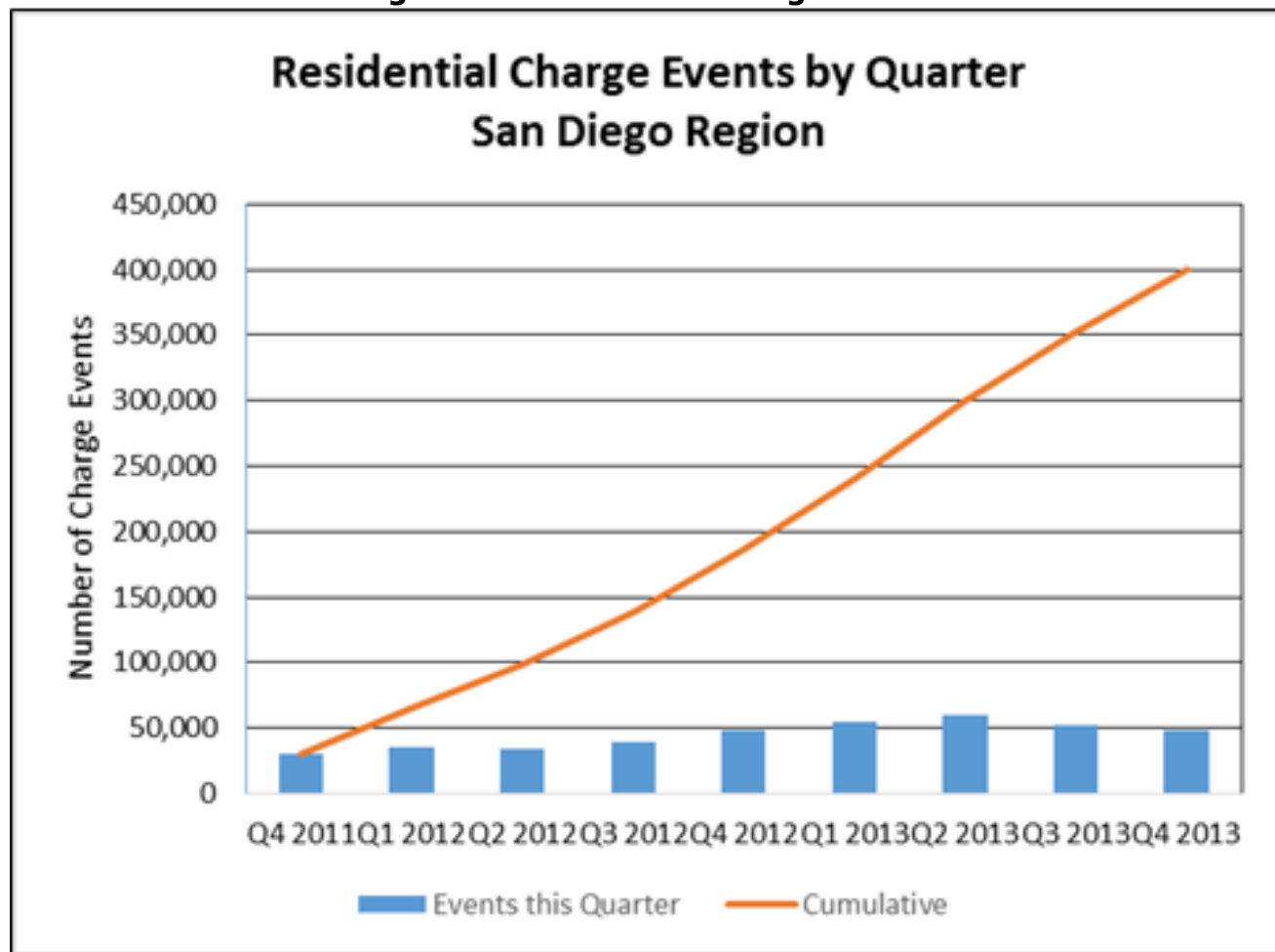
Data filtering is a significant portion of any data collection and analysis project. The EV Project expended significant resources in collecting, filtering and storing data from which the reports and observations flow. As of December 2013, the project reported data on 124 million miles recorded on EV Project vehicles and over 4 million charging events recorded throughout all regions. This data was collected and delivered from over 20,000 discrete data sources operating in an uncontrolled environment for two years. The San Diego region recorded over 19 million miles and over 633,000 charge events from over 2,500 discrete data sources (PEVs and EVSE units).

Residential EVSE Data

As the quantity of participants grew, so did the number of charge events. Figure 29 shows the growth in charge events in San Diego as reported in the quarter reports. (Note that some differences in numbers of events may exist because of EV Project aggregation rules.) As above, this information originated in the quarterly reports. As noted previously, some participants declined to continue participation in the project past the original scheduled date

of December 31, 2012. Because their agreement to provide data thus terminated, the data reported for Q1 and Q2 2013 does not include data from these retired participants. As above, the decline in charge events in the last two quarters of 2013 is likely a result from the bankruptcy influence on unit use and servicing.

Figure 29: Residential Charge Events



Source: Blink Network

Residential charge events provide the basis for many analytical reports such as: home vs away- from-home charging statistics, vehicle (and charger) usage changes over time, driver behavior differences between those who charge away-from-home and those who do not, average daily vehicle utilization, etc. In addition, there are several topics that are of interest specifically to electric utilities, such as clustering events, load impacts, impact of time-of-use rates, estimation of load based upon EV adoption, etc. Section 4.4.2 provides observations on these questions.

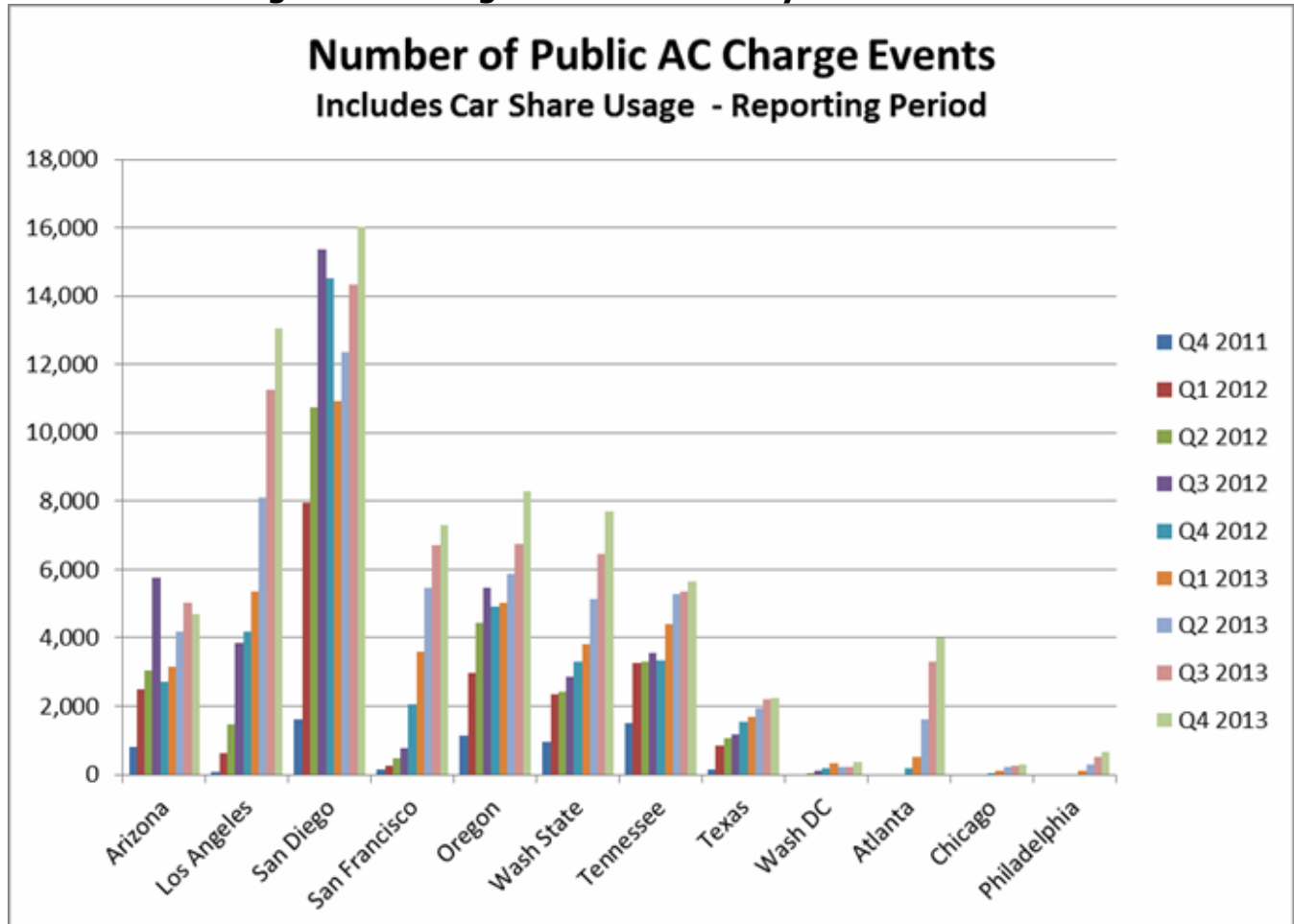
Non-Residential EVSE Data

Non-residential EVSE include publicly accessible, fleet and workplace EVSE. In the fourth quarter of 2012, the quarterly reports separated the non-residential into their component parts. The following sections analyze the individual components as it relates to the collection of data.

Publicly Accessible EVSE Data

The San Diego region is distinctive in utilization of the public infrastructure in that a significant percentage of the charging occurs by the car sharing program. Section 4.4.6 provides more information on the Car2Go impact. Figure 30 shows a comparison of publicly accessible EVSE charge events for all regions of the EV Project.

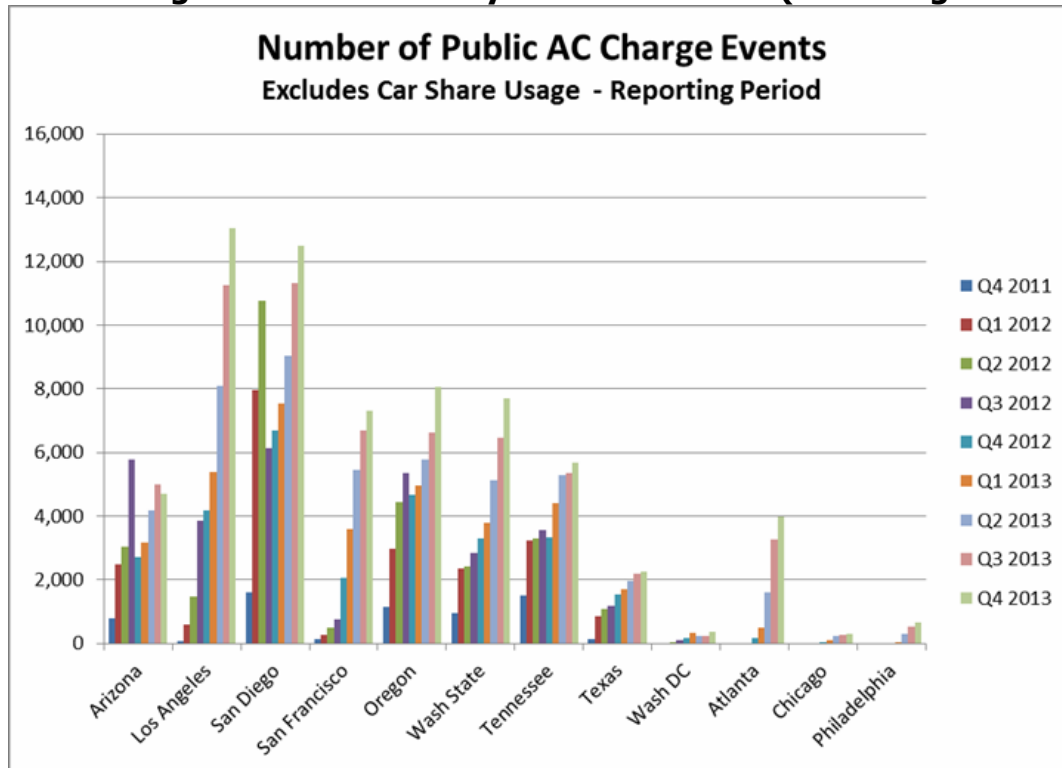
Figure 30: Charge Events at Publicly Accessible EVSE



Source: Blink Network

Excluding the Car2Go charge events, the San Diego still excels in the use of publicly accessible EVSE compared to all regions as shown in Figure 31.

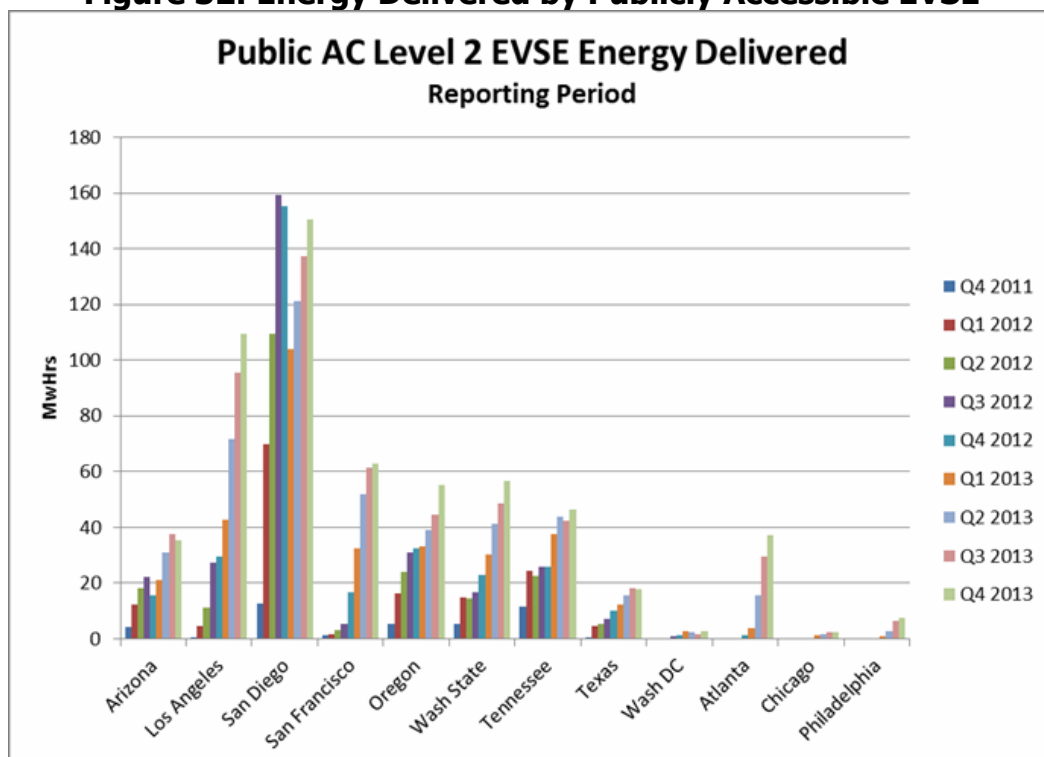
Figure 31: Charge Events at Publicly Accessible EVSE (excluding Car Sharing)



Source: Blink Network

This utilization of publicly accessible has an impact on the energy delivered by these EVSE. See Figure 32.

Figure 32: Energy Delivered by Publicly Accessible EVSE



Source: Blink Network

Publicly accessible charge events provide the basis for many analytical reports such as: home vs away-from-home charging statistics, vehicle (and EVSE) usage changes over time, driver behavior differences between those who charge away-from-home and those who do not, identification of best locations for EVSE siting, etc. In addition, there are several topics that are of interest specifically to electric utilities, such as load impacts, impact of car sharing programs, estimation of load based upon EV adoption, etc.

Fleet and Workplace EVSE Data

Because significantly fewer fleet EVSE deployed compared to the total AC Level 2 and several locations would then fail to meet the aggregation number, the quarterly reports grouped fleet and workplace into the non-residential private category in the quarterly reports.

Fleet charge events are of interest because of the potential impact on the electric grid for daytime charging. Some fleet operations charge vehicles at all times of the day while others charge vehicles only at the end of the working day. The mission and purpose of the fleet vehicles and their power requirements dictate the recharge strategy.

Workplace charging is of interest because a significant number of participants indicated they have access to workplace charging and use it. An EV Project survey conducted of all project participants revealed:

41 percent of survey respondents who use their plug-in electric vehicle (PEV) for work report having the availability of charging at their workplace.

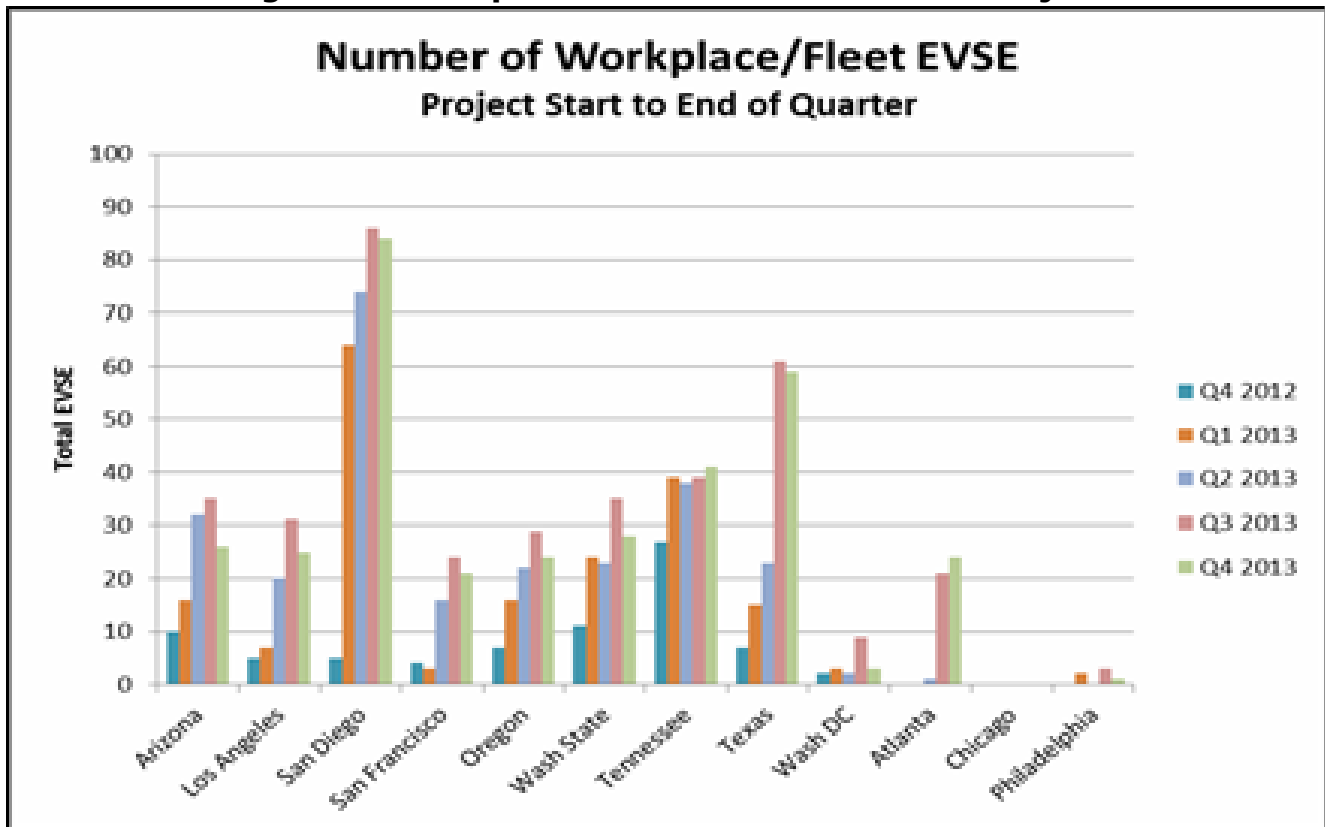
For those who have workplace charging available, nearly twice as many report AC Level 2 as Level 1.

36 percent of respondents report workplace charging is very important or essential to meeting their PEV driving needs.

Workplace charging data is also important for analysis of electric utility load impacts, shifting some of the EV driver demand from at night at home to work in daytime hours, impact on the use of publicly accessible EVSE, etc.

Again, the enthusiasm in the San Diego for adoption of PEVs into the workplace and in fleets is evident by the solicitation of these owners for EVSE from the EV Project. By far, San Diego exceeded other regions in the desire for these EVSE as shown in Figure 33.

Figure 33: Workplace and Fleet EVSE in the EV Project



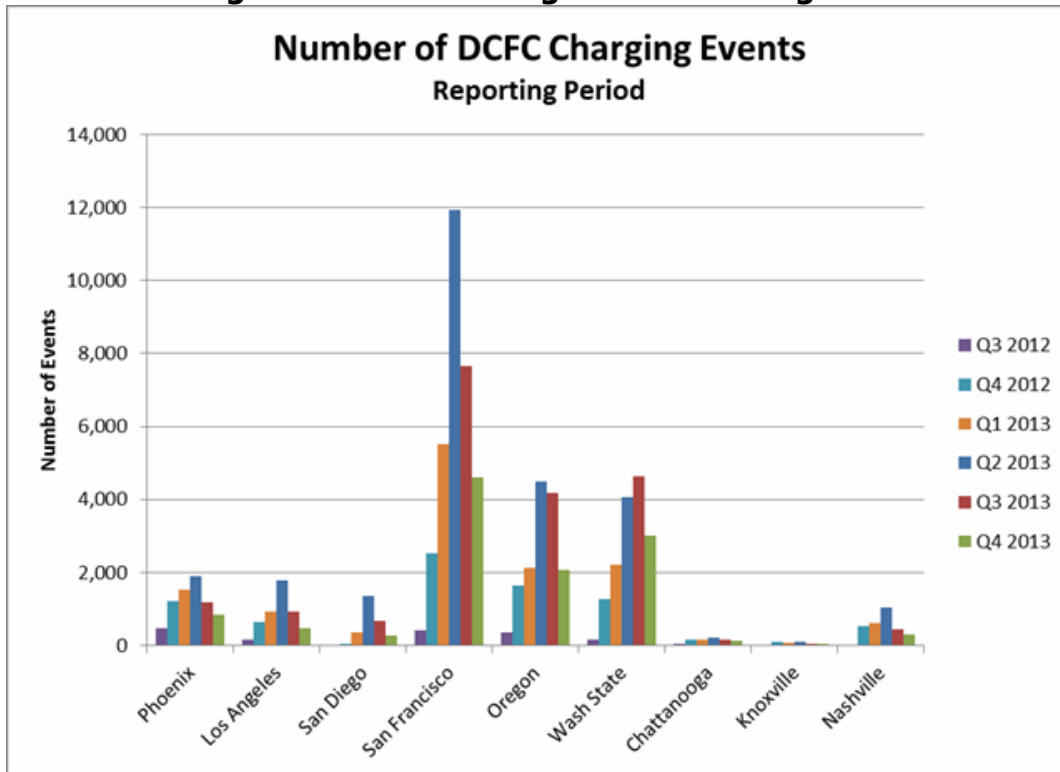
Source: Blink Network

The EV Project study was of the interaction of EV Project vehicles with EV Project charging stations. Fleet owners were eligible for the EVSE if they also included EV Project vehicles for their fleet applications. Workplace employers were not required to include vehicles to be eligible for EV Project charging stations.

DC Fast Charger Data

Because the quantity of DCFC in the San Diego region is less than the aggregated minimum of ten, there is little information available specific to the San Diego region in the published EV Project quarterly reports. This report provides more information. Figure 34 shows the relative number of charge events for all DCFC in the project.

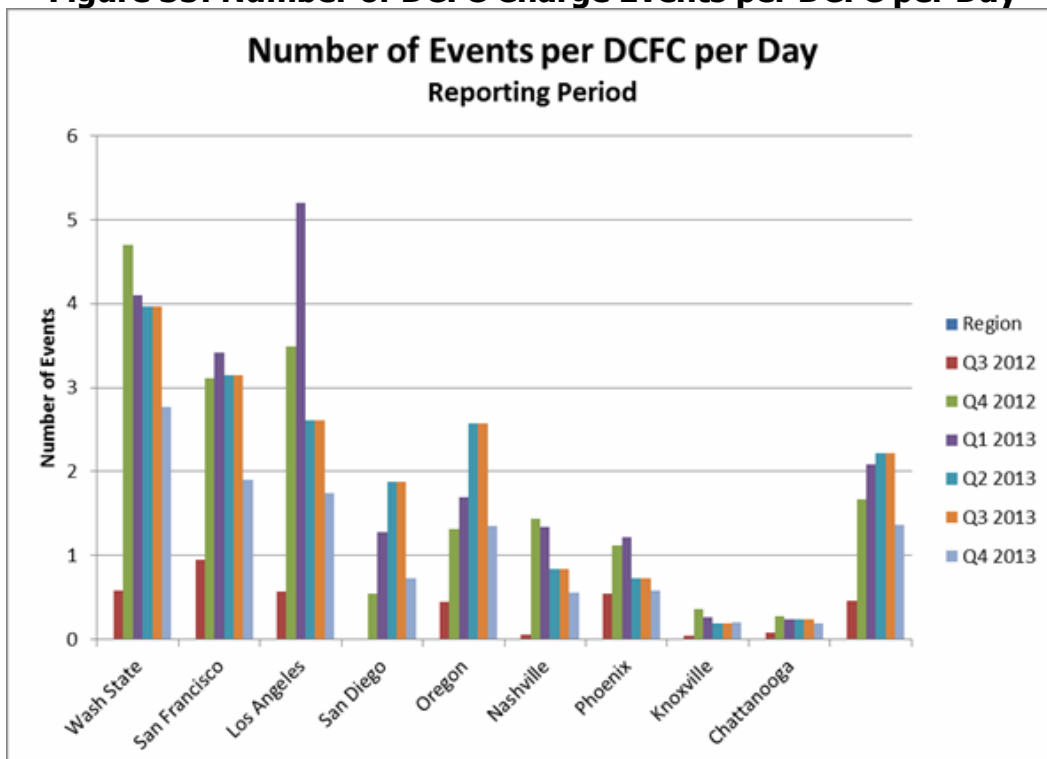
Figure 34: DCFC Charge Events all Regions



Source: Blink Network

Because the number of DCFC in each area varies so much, another look at the charge data is per DCFC unit. Figure 35 displays that information.

Figure 35: Number of DCFC Charge Events per DCFC per Day



Source: Blink Network

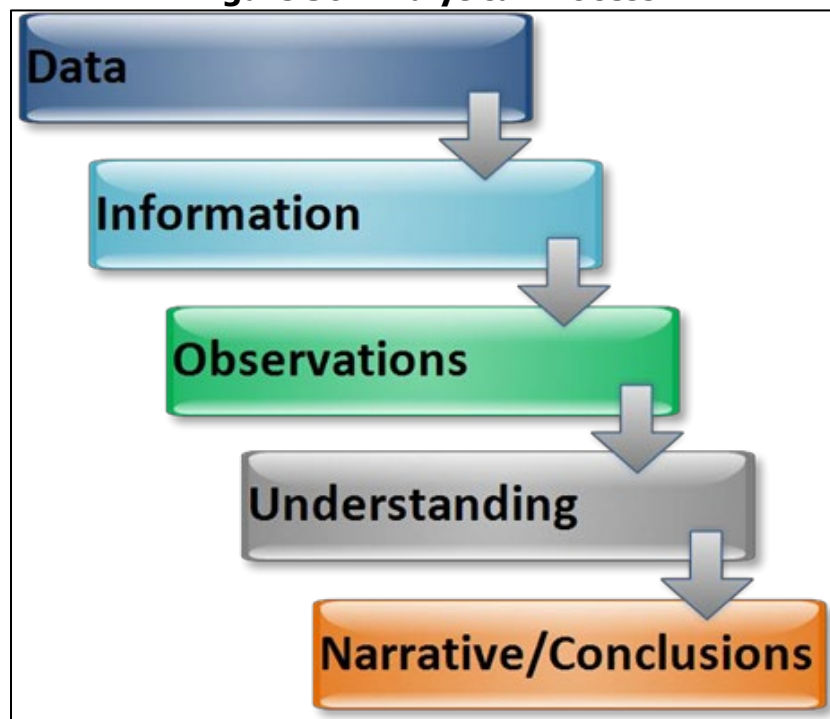
DCFC utilization on a per unit basis plateaued in mid-year 2013 and dropped after that. The utilization in San Diego area had a very high peak in the first quarter 2013 but also experienced a significant drop. The reason for the decline is uncertain but is likely a result of ECotality bankruptcy issues and the introduction of access fees.

Observations

The analytical process generally follows that outlined in Figure 36 below. The collection, filtering and storage of data occur. A study of those data yield information useful for further analysis. The EV Project quarterly reports provide an example of such information.

A more detailed look at the information and data yields observations. Combining observations yielded understanding of the subject. Combining understandings yields conclusions or changes to the narrative related to the subject. The project's publication of lessons learned provides observations and understanding and may be instrumental in changing narratives related to the use of EVs.

Figure 36: Analytical Process



Source: Blink Network

Deployment Plan Evaluation

The project schedule anticipated completion of the non-residential EVSE location planning activities prior to the delivery of the first PEV and prior to the installation of the first EVSE. With little prior history in the location analysis of public charging, the project developed the Micro-Climate planning process. The next question is how effective were the enrollment of charging site and hosts in the plan implementation.

The project assessed the effectiveness of this deployment and published the results: The EV Micro-Climate® Deployment Process in San Diego⁹ (Appendix S) on the EV Project website. The following provides an overview and the significant conclusions reached in this assessment.

All group member organizations provided input on the data used in the Micro-Climate plan. The varied focus, both subject area and geographic, of the advisory group member organizations ensured consideration of a broad set of data, under such general categories as land use, transportation, market research, electric grid capacity, and driver behavior. The group represented each of these functional responsibilities. Group organizations also provided access to data available within their organizations to facilitate the Micro-Climate planning process.

The base unit of geography for the model was Master Geographic Reference Areas (MGRAs), a proprietary data unit designed and used by SANDAG, who provided the majority of the geographic information systems modeling and mapping support. MGRAs are geographic areas roughly the size of census blocks in urban and suburban areas, and census block groups in rural areas. MGRAs nest into larger standard geographies, such as census tracts, zip codes and municipal boundaries. They present in a way that preserves the contiguity of trip producing and attracting land uses. MGRAs are polygon shapes rather than points but contain the points of interest (POI) which should attract PEV drivers. An MGRA may contain more than one POI, but the evaluation focused on the MGRA level rather than the POI level. Maps generated including the MGRAs and a ¼ mile buffer that had the greatest potential of optimum EVSE sites within them.

Optimum Level 2 EVSE locations are those locations with:

High number of users

- Integrated into daily life
- Available to many different users

High frequency of vehicle turnover

- Vehicle stay times of 45 minutes to approximately 3 hours

Significant availability

- Maximize the number of open days per week and per year
- Maximize the number of open hours per day

The advisory group rated the different categories of sites on a scale of 1 to 5, with 5 being the highest value MGRA. After the application of their selected weighting factors and normalizing the results, the final scale provided the top two tiers of targeted locations. A ¼ mile radius centered on the MGRA provided a region within which a driver would likely walk to the POI from an EVSE parking location. A total of 3,333 ¼ mile circles resulted in the San Diego area.

⁹ [The EV Micro-Climate Deployment Porcess in San Diego](https://avt.inl.gov/sites/default/files/pdf/EVProj/112390-451046.mcproc-sd.pdf)

<https://avt.inl.gov/sites/default/files/pdf/EVProj/112390-451046.mcproc-sd.pdf> [accessed April 5, 2014]

This represents the top 18 percent of the 18,756 MGRAs. Because the MGRA size varied, the ¼ mile circle may contain several MGRAs and POIs.

At the time of the evaluation in March 2013, deployment consisted of 435 non-residential AC Level 2 EVSE or 82 percent of the final deployment. The report concludes that 97 percent of the deployed publicly accessible EVSE provided services to targeted MGRAs. In addition, 34 percent of these 3,333 targeted MGRAs contain a publicly accessible EVSE.

In mid-year 2012, UC Davis conducted a survey of San Diego participants as part of a sub-award within the EV Project. This survey occurred prior to the completion of the infrastructure deployment. Among the questions were requests for the respondents to identify desired public charging locations. In their report, UC Davis also performed an evaluation of the actual deployment per the plan and the deployment against the desired locations. The methodology used by UC Davis differed from the one referenced above. UC Davis selected the top 1,000 MGRAs (top 5 percent) to compare actual installations. UC Davis also evaluated how closely the plan compared to the survey participants desired locations and how closely the actual deployment compared to the desired locations. The document, *California Statewide Charging Survey: What Do Drivers Want? UCD-ITS-RR-13-02¹⁰* provides the complete report.

At the time of the UC Davis survey in early 2012, there were 461 Leaf owners in the San Diego region with 271 responders to the survey. There were approximately 100 publicly accessible EVSE deployed at that time. Two conclusions drawn from this report are that 73 percent of the respondents desired locations are within the planned ¼ mile buffer area. This appears to validate the planning process in that locations planned prior to any PEV availability did meet with high approvals from the early adopters. Second, while 98 percent of EV owners desired locations are within 5 miles of an installed EVSE, only 26 percent of the desired locations were within ¼ mile of an installed EVSE.

It is noted that the survey was completed early in the deployment of the publicly accessible EVSE and driver awareness of existing locations is uncertain. Certainly, their experience in the use of public infrastructure was in its infancy.

Further study related to utilization of the public EVSE within the regions desired by the survey respondents is warranted. Do drivers use the public EVSE that are located at or near their stated desired locations?

Residential Enrollment Observations

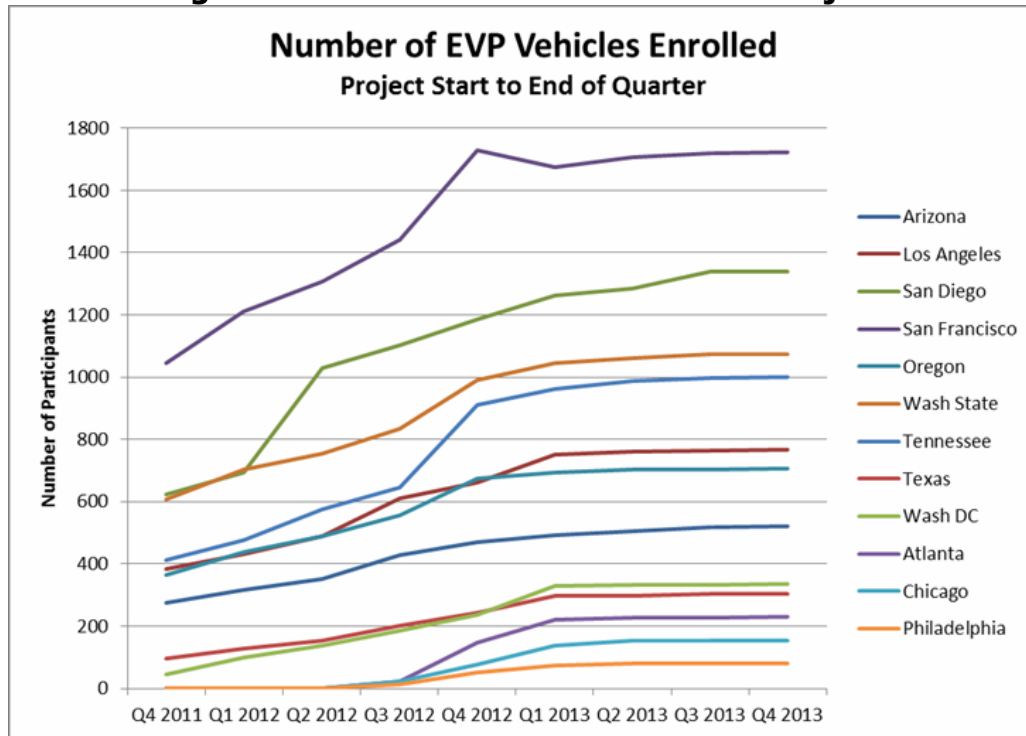
Figure 37 shows the growth in project participation from the first quarter 2011 for all regions. The EV Project tried to present a consistent marketing effort in the project regions and offered incentives for participation. However, the reduction in the monetary incentive in August 2012 (Q3 2012) had little effect on the increasing rate of participation. It is also interesting to note the different times as which markets had obvious increases or decreases in the rate of participation. Local market forces, such as marketing efforts by state or local

¹⁰ [California Statewide Charging Survey: What Do Drivers Want?](http://www.its.ucdavis.edu/research/publications/publication-detail/?pub_id=1829)

http://www.its.ucdavis.edu/research/publications/publication-detail/?pub_id=1829 [Accessed April 6,2014]

government, vehicle dealers, electric utilities, etc. likely drove these changes in adoption rates. The figure shows the enthusiasm in the San Diego region.

Figure 37: Vehicles Enrolled in the EV Project



Source: Blink Network

Figure 38 shows the density of participants enrolled by zip code.

Figure 38: Residential Participation Density



Source: Blink Network

Because the population and numbers of households within zip codes vary considerably, a more accurate depiction of the adoption of PEVs within the project is by 1000s of households within the zip code. Figure 39 displays these results.

Figure 39: Residential EVSE per 1000 Households (2010 Census)



Source: Blink Network

Figure 40 reflects the adoption rate for the EV Project by zip code. Figure 39 shows the area income density (2007 census data) for comparison.

Figure 40: San Diego Average Household Income Density (2007 Census)



Source: Microsoft MapPoint 2013

Not surprisingly, there is a good correlation between income level and EV ownership/participation. This led to a study of the participants' demographics noted below.

Participant Demographics

Because this was primarily a study about infrastructure use and not merely a deployment of EV charging infrastructure, certain acceptance criteria were established for participation in order to assist timely deployment and analysis. Acceptance for participation in the project meant that the prospect met the following criteria:

- Owned their own residence (typically a single-family home)
- Lived and kept their vehicle within the project's study market boundary
- Purchased or leased a Chevrolet Volt or Nissan Leaf
- Agreed to pay any installation costs that exceeded the project incentive
- Had wireless internet connection in their home and allowed its use for data transmission
- Agreed to stay enrolled in the project until the end of the project

The Leaf drivers typically enrolled on the waiting list for the Leaf in early 2010 and some waited a considerable time to take delivery. In the summer of 2013, a survey of EV Project participants revealed the following:

- The typical EV Project participant resides within 40 miles of a major metropolitan center, in an owner-occupied, single-family residence.
- 63 percent of the primary drivers of the Plug-in Electric Vehicles (PEV) are male.
- The average age of the driver is 50.9 years.
- The average income of participant households is \$148,811 with more than 30 percent earning more than \$200,000 annually.
- 84 percent of the primary drivers have college degrees with 44 percent having advanced degrees.

The EV Project provided funding to UC Davis to conduct surveys of San Diego participants early in 2012. The resulting paper: *Who is Buying Electric Cars in California? Exploring Household and Vehicle Fleet Characteristics of New PEV Owners*; UCD-ITS-RR-13-02 (Appendix U) provides demographic and use information on these early adopters.

UC Davis followed this survey process in San Diego with several interviews and focus group discussions again funded by The EV Project. The interviews occurred in March and April 2012 with the focus group discussions following in the fall of 2012. The results are reported in the paper *Community and Social Media Use among Early PEV Drivers*: UCD-ITS-RR-13-11. One of the conclusions reached at this early date was:

"The PEV drivers we interviewed show wide variation in their descriptions of who they believe PEV drivers to be, conceptualizations of a PEV community, uses of social media, and social interactions with other PEV drivers. Respondents often described other PEV drivers in relation to themselves: like or not like. PEV drivers are far from united in their belief in "PEV communities." Those who affirmed or conditionally affirmed the existence of a PEV community are divided as to their active participation in such a community—even to the extent to whether they want to participate. The reasons for identifying with or not identifying

with the community varied. At present there is no singular description of PEV drivers or a PEV community, however the shared themes indicate some common ideas of both. These results indicate that most of the participants are still in a process of discovery: they are evaluating other PEV drivers, their ideas of a PEV community, and how they position themselves in relationship to both.”

The EV Project residential participant survey was conducted at the completion of the enrollment period. It posted the complete report: *Who are the Participants in the EV Project?*¹¹ on the EV Project website in August 2013. There were approximately 3,063 respondents to the survey with approximately 359 participants from San Diego. This response rate represented approximately 42 percent of all participants at the time; a very good result. Approximate numbers are used since not all respondents answered all questions.

Figure 41: San Diego Participant Average Household Income

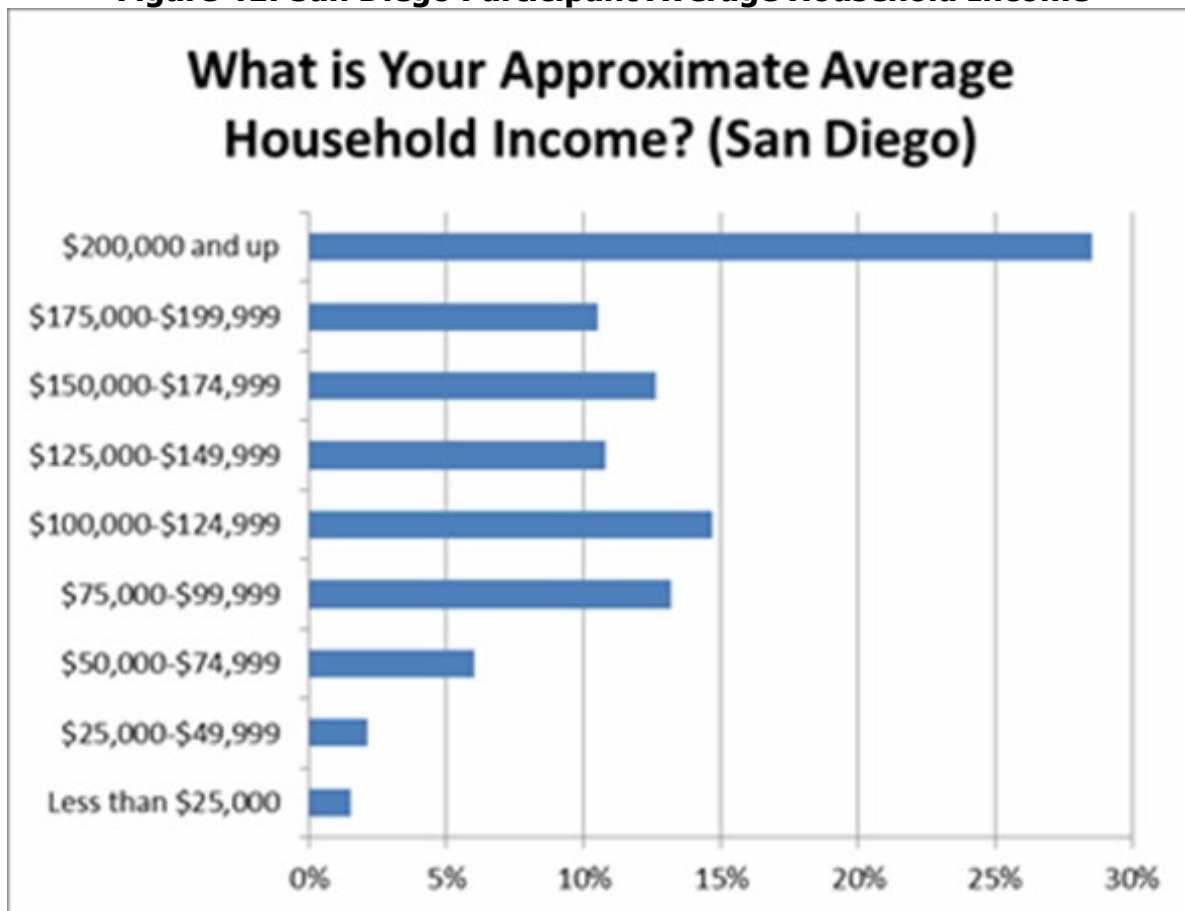
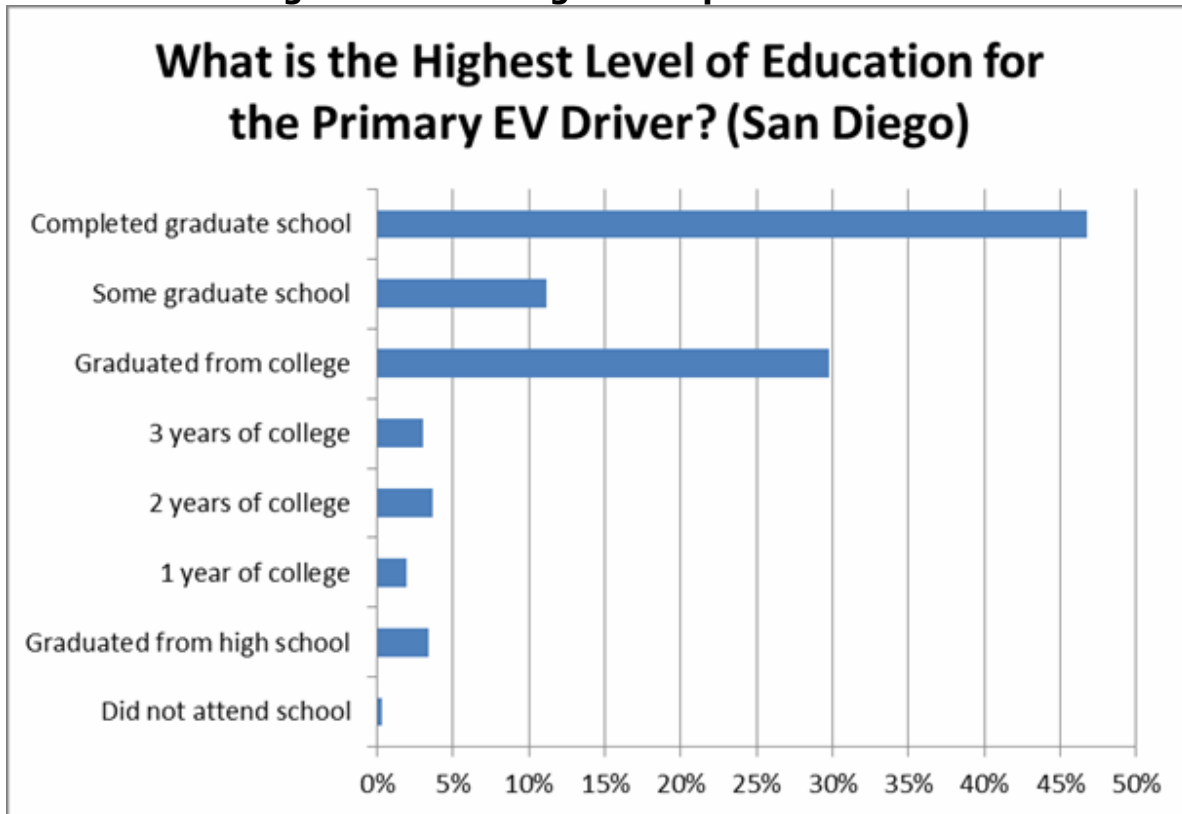


Photo Credit: Blink Network

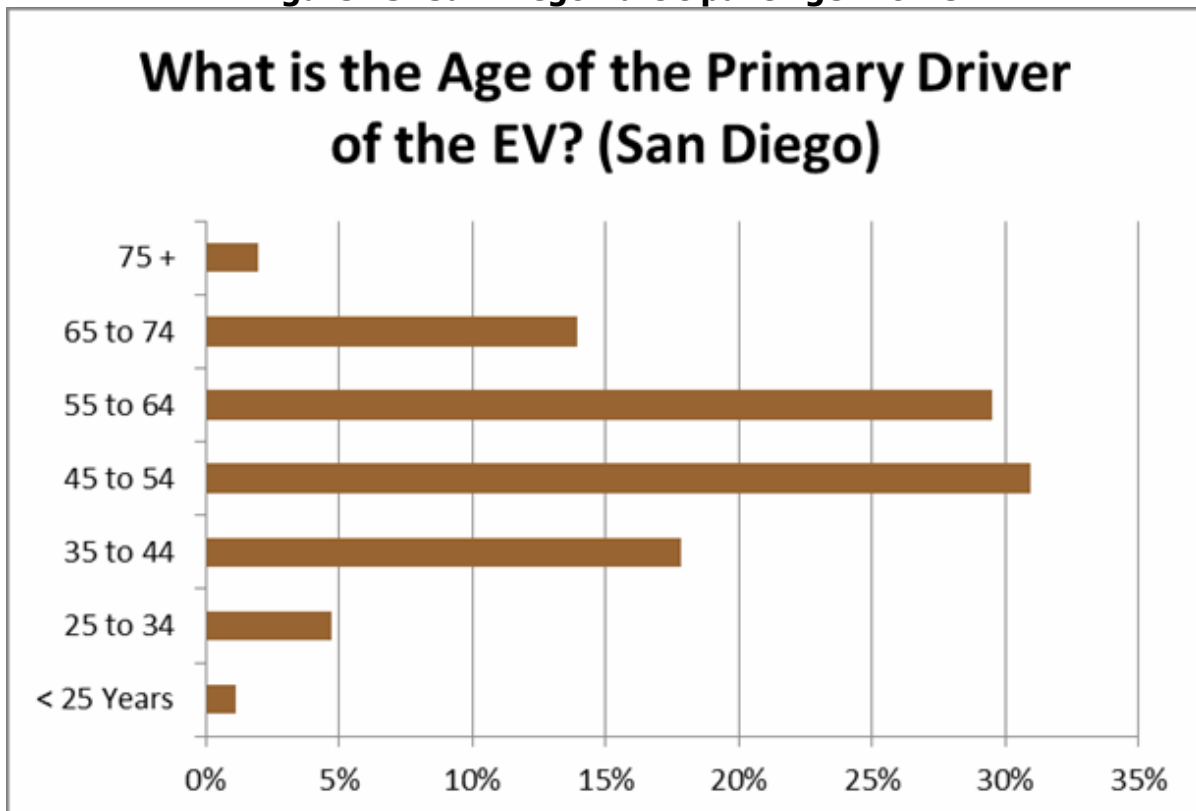
¹¹ [Who Are the Participants in the EV Project?](https://avt.inl.gov/sites/default/files/pdf/EVProj/128842-80098.devproj.pdf) <https://avt.inl.gov/sites/default/files/pdf/EVProj/128842-80098.devproj.pdf> [Accessed April 6, 2014]

Figure 42: San Diego Participant Education



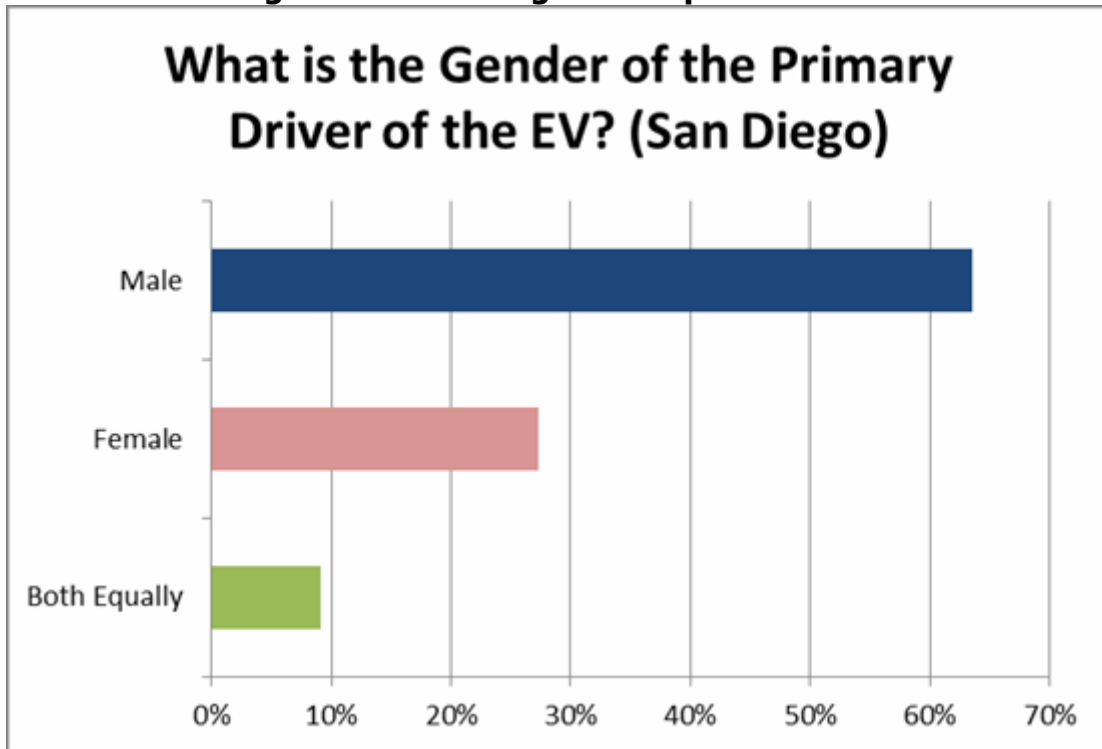
Source: Blink Network

Figure 43: San Diego Participant Age Profile



Source: Blink Network

Figure 44: San Diego Participant Gender

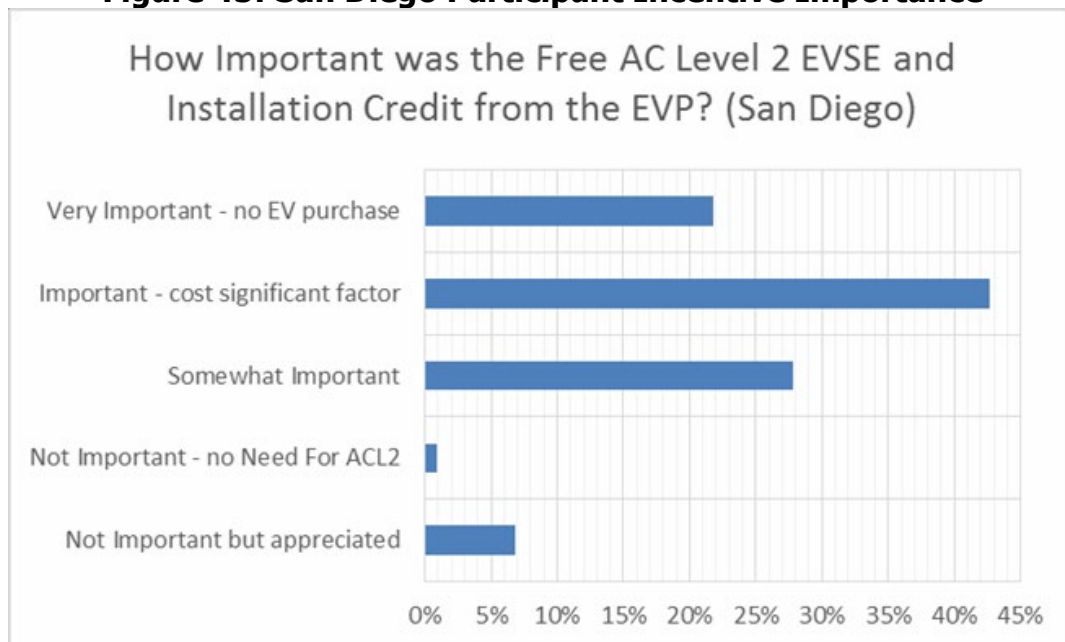


Source: Blink Network

The Gender and income are close to the national average while the San Diego participant is slightly older, and a higher percentage has advanced degrees than the national average.

The survey asked how important was the incentives of the free residential EVSE and installation credit in the participant's decision to obtain the EV. Figure 45 shows the responses.

Figure 45: San Diego Participant Incentive Importance



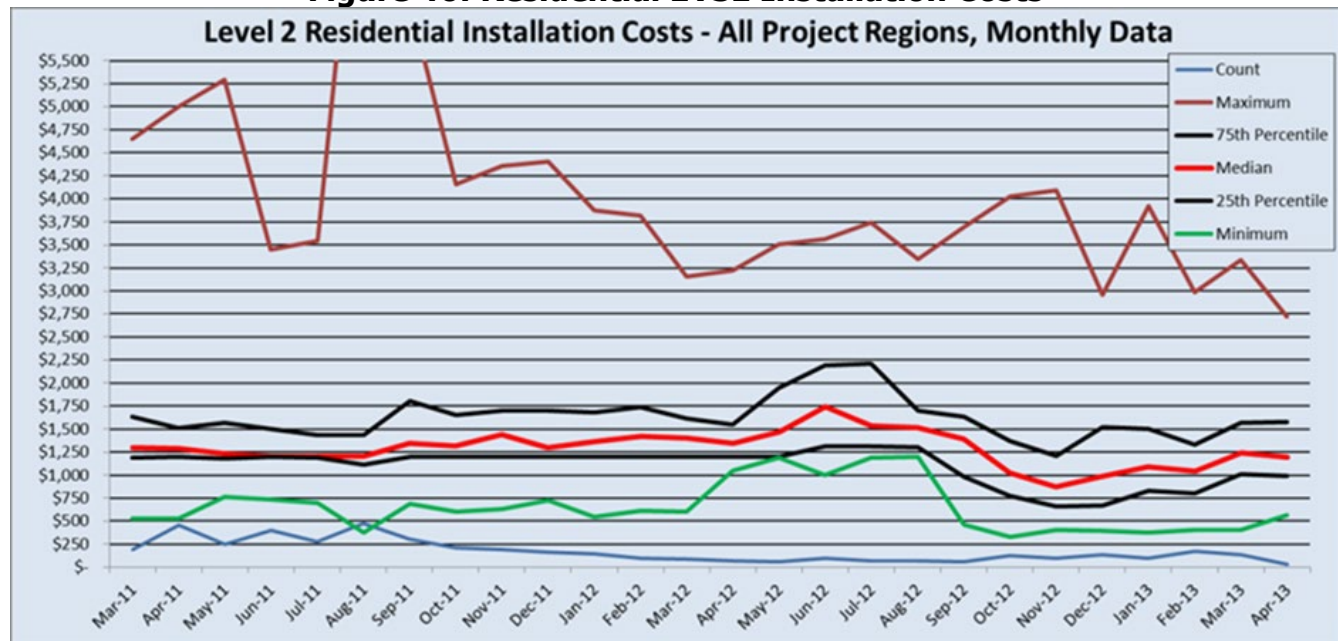
Source: Blink Network

It is noteworthy that 22 percent of the participants said that they would not have obtained an EV without the incentives associated with the EV Project.

Residential EVSE Installation Costs

The installation cost for residential EVSE is of high interest to potential PEV owners, electrical installation contractors, OEMs and EVSE suppliers. The potential buyer will know the cost of the PEV and the cost of the EVSE selected but does not know the cost of installation until an electrical contractor provides a quote following a visit to the residence. The project collected installation costs in detail through April 2013. Nationally, 4,466 residential sited AC Level 2 EVSE averaged \$1,300 for the installation costs excluding the EVSE and permit fees. Figure 46 shows the results of this national analysis.

Figure 46: Residential EVSE Installation Costs



Source: Blink Network

The project budget allowed an incentive to the participant of credit toward the installation cost. The credit was \$1200 in the early stages of the project but reduced to \$400 in August 2012.

Without additional funding, the adjustment was necessary in order to extend the enrollment period in an attempt to meet enrollment targets. This change also provided an opportunity to evaluate the impact of the size of the incentive. In both cases, the participant paid any installation costs exceeding the incentive.

The median installation cost (less permits) is fairly close to this \$1,200 value through most of 2011 and into 2012. As the incentive dropped, so did installation costs until they rebounded near the \$1,250 median in first quarter 2013. This suggests that some electrical contractors were “aware” of the incentive in their installation quotes. Several installations were well below this median value indicating some very easy installations while some installations were considerably higher than the median which suggests very difficult installations.

The average for all installations (excluding EVSE) was \$1,414. The maximum was \$8,429; the minimum was \$250 and the median \$1,265.

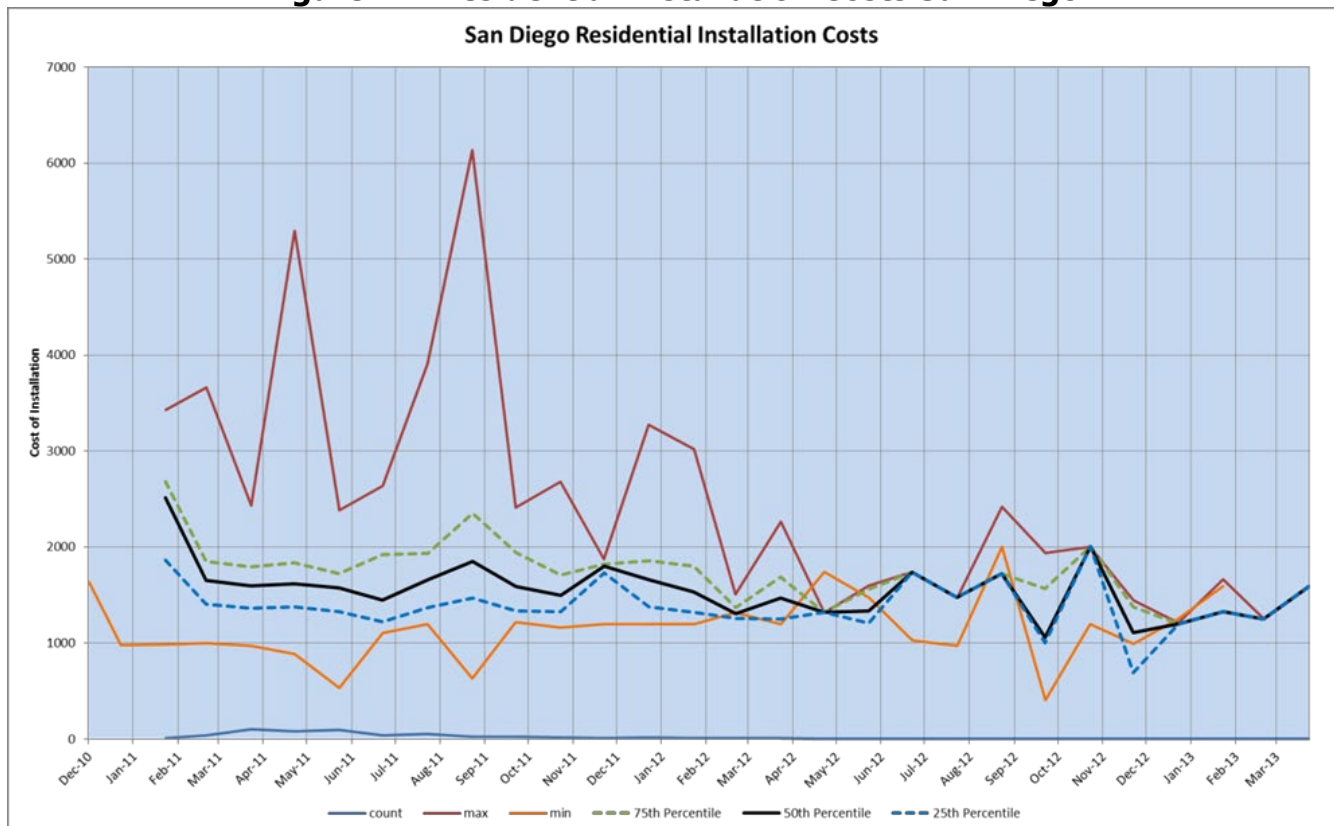
The high cost drivers were:

- Upgrading the residential electrical service (\$8,429)
- installation location far from electrical service panel
- detached garage or parking location not adjacent to the home
- concrete, asphalt or other surface cuts and repairs
- The low-cost drivers were:
- existing 240-volt outlet already installed in the garage (\$250)
- Easy installation where the conduit run is short, and a simple breaker addition was required
- Existing space in the garage near the breaker panel

Figure 47 displays the installation costs specific to San Diego that are part of this study.

The average for all installations (excluding EVSE and permit fees) was \$1,650. The maximum was \$6,132; the minimum was \$404 and the median \$1,596.

Figure 47: Residential Installation Costs San Diego

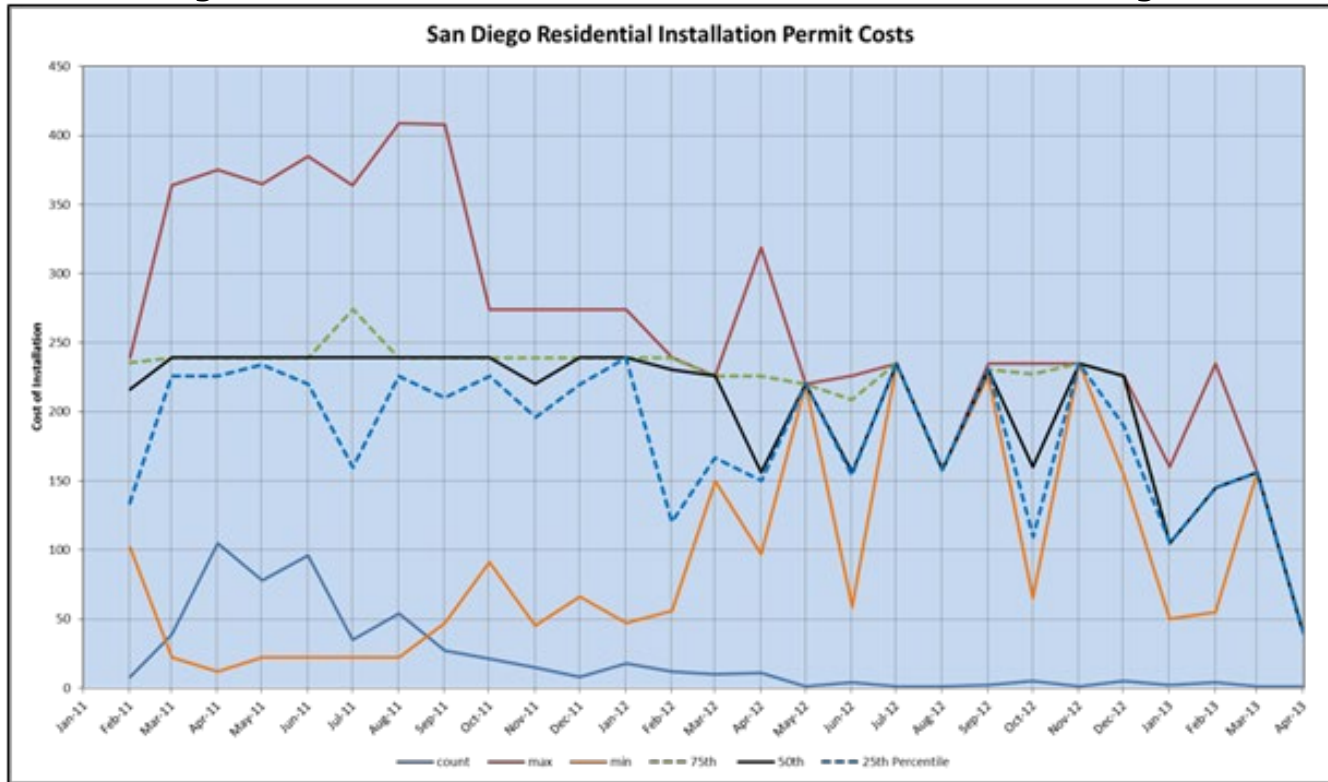


Source: Blink Network

In San Diego, SDG&E conducted a special rate evaluation in conjunction with the EV Project for Leaf participants who enrolled. It required the installation of the second meter to monitor the EVSE usage and bill this usage separately from the whole house. SDG&E provided this

installation and no costs are included in the above report. The permit fees required by AHJs is another cost of installation beyond the control of the contractor. The project found wide variation in these fees between jurisdictions. Figure 48 shows the permits fees encountered by the project in the San Diego region.

Figure 48: Residential EVSE Installation Permit Fees San Diego



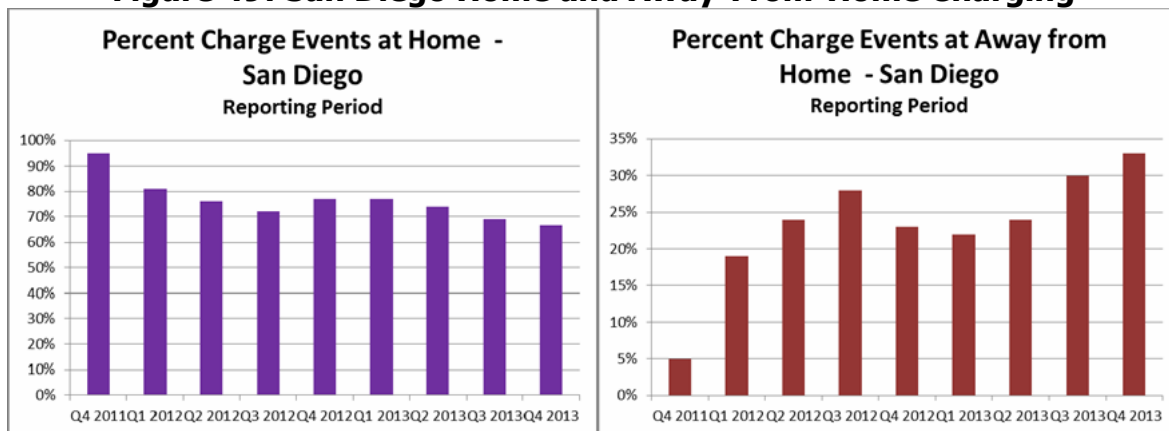
Source: Blink Network

The average for all permits was \$213. The maximum was \$409; the minimum was \$12 and the median \$239. Nationally, the average for all permits was \$114. The maximum was \$985; the minimum was \$3 and the median \$89. This is an area that should receive greater scrutiny for the promotion of PEVs.

Home Charging by Participants

Most PEV charging occurs at the residence. Figure 49 shows the percent of all charge events in the San Diego region that occurred at home and away-from-home over the project period using the quarterly report information. The initially high use at home was clearly influenced by the lack of available units for away-from-home charging, which did not mature until later in 2012.

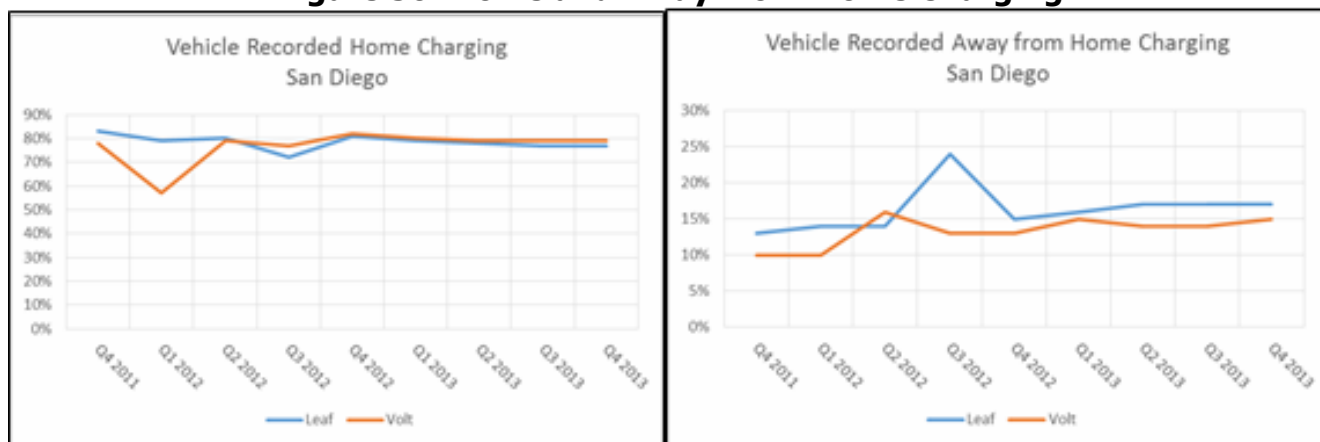
Figure 49: San Diego Home and Away-From-Home Charging



Source: Blink Network

The above graphs data originated from the EVSE charge information and include Car2Go charge events. Figure 50 shows the individual Nissan Leaf and Chevrolet Volt graphs for home charging and away-from-home charging. While these graphs follow the same trend for increasing away-from-home usage, the influence of the car sharing use of public charging is evident. Section 4.4.6 explores this further.

Figure 50: Home and Away-from-Home Charging



Source: Blink Network

The participant survey also asked of the importance of charging away from home. The responses to the question may differ based upon whether the participant owns a Volt or Leaf. Because the quantities of each differ in the responses, both the numbers and percentage of all responses for that vehicle are provided. Table 7 provides the results for San Diego.

Table 7: San Diego Participant Charging Importance

Charging Needs in San Diego	Leaf Owner	Volt Owner	Owner of Both	Overall
Never use charging away from home	54 23%	38 36%	0 0%	92 26%
Occasionally use charging away from home	163 69%	53 50%	5 71%	221 63%
Frequently use charging away from home	12 5%	5 5%	1 14%	18 5%
Rely on away-charging as much as home-charging	3 1%	7 7%	0 0%	10 3%
Mostly use charging away from home	3 1%	0 0%	1 14%	4 1%
Rarely, if ever use home charging	0 0%	0 0%	0 0%	0 0%
Away-from-home charging not available in my area	1 0%	3 3%	0 0%	4 1%

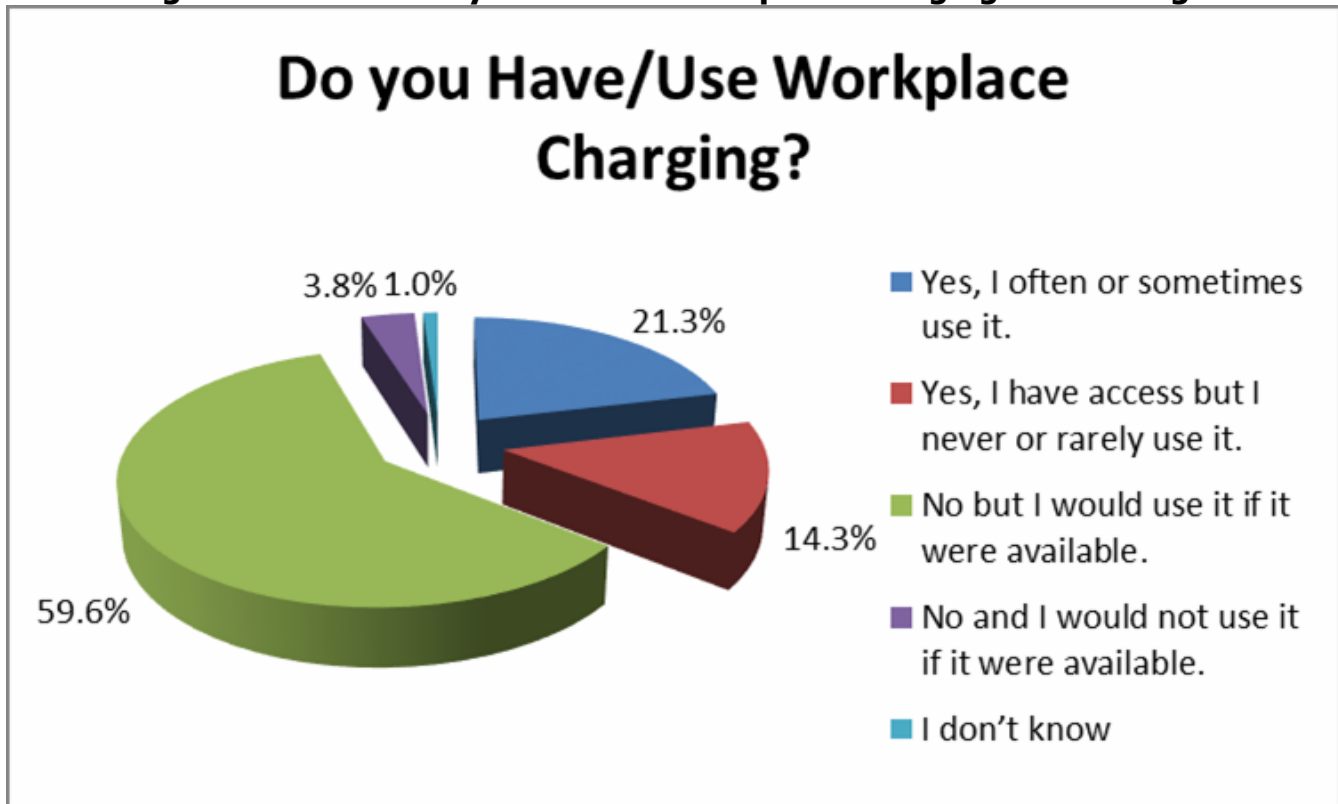
Source: Blink Network

The percentages of those who never use away-from-home charging are higher than the national average for both the Leaf and the Volt. In general, there is a shift in all San Diego responses toward the lower use of away-from-home charging.

Away from Home Charging by Participants

Participants charge away-from-home either in publicly accessible EVSE or at the workplace. In the survey noted above, San Diego participants responded on the use of workplace charging as noted in Figure 51.

Figure 51: Availability and Use of Workplace Charging in San Diego

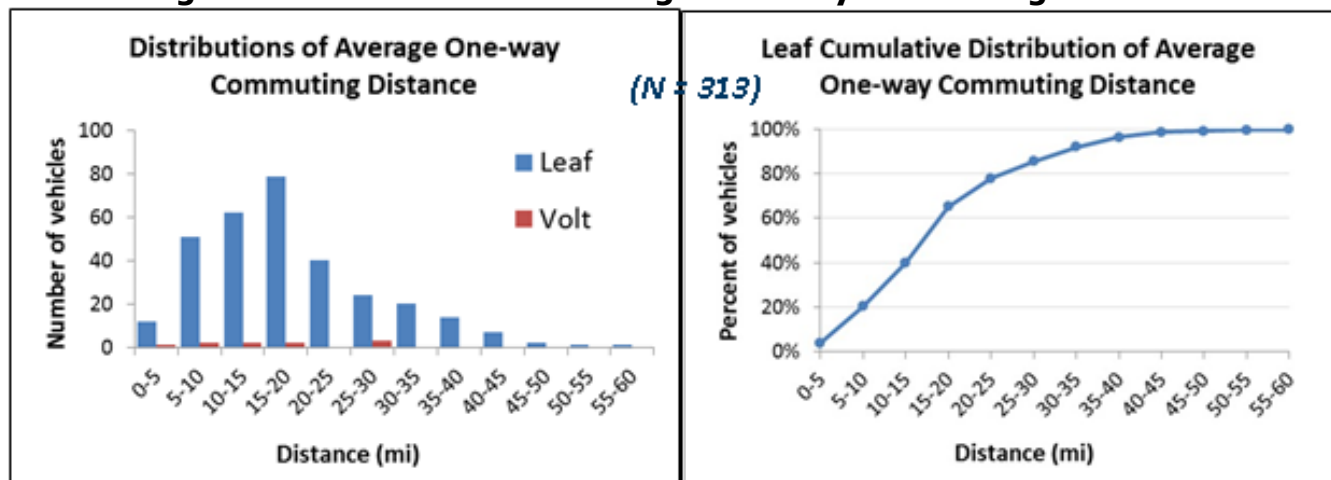


Source: Blink Network

At the time of the survey in San Diego, 35.6 percent of responding participants had access to workplace charging. Nationally, 41 percent of respondents had access. Of interest above is the percentage of those who have access but never or rarely use it.

Using vehicle GPS charge data along with EV Project EVSE at those coordinates resulted in a study of workplace charging. 86 percent of EV Project Leafs parking at worksites identified an average 30 miles or less between home and work. Figure 52 shows the distributions of commuting distances.

Figure 52: Distribution of Average One-Way Commuting Distance

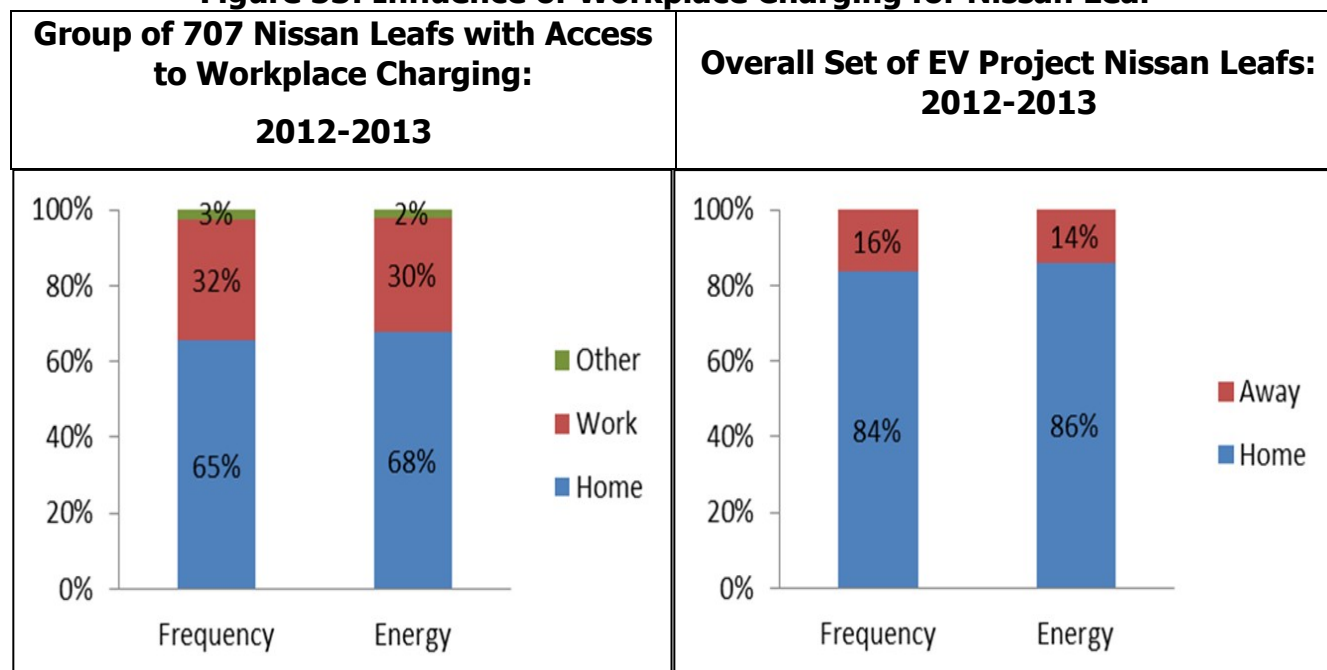


Source: Idaho National Laboratory

One reason persons do not charge at work even though it is available may be that they don't need to charge at work because their EV has sufficient range without charging. The workplace conditions and rules for charging, including any fees that might be accessed, is unknown and would likely influence the participants desire for this charge.

The project conducted an analysis of driving behavior by persons who have access to workplace charging. The paper "Where do Nissan Leaf drivers in the EV Project charge when they have the opportunity to charge at work?"¹² reports the results. People, who do charge at work, charge less at home and in public. Figure 53 shows the results of this analysis. The "frequency" identifies the number of charge events while the "energy" identifies the energy transferred.

Figure 53: Influence of Workplace Charging for Nissan Leaf



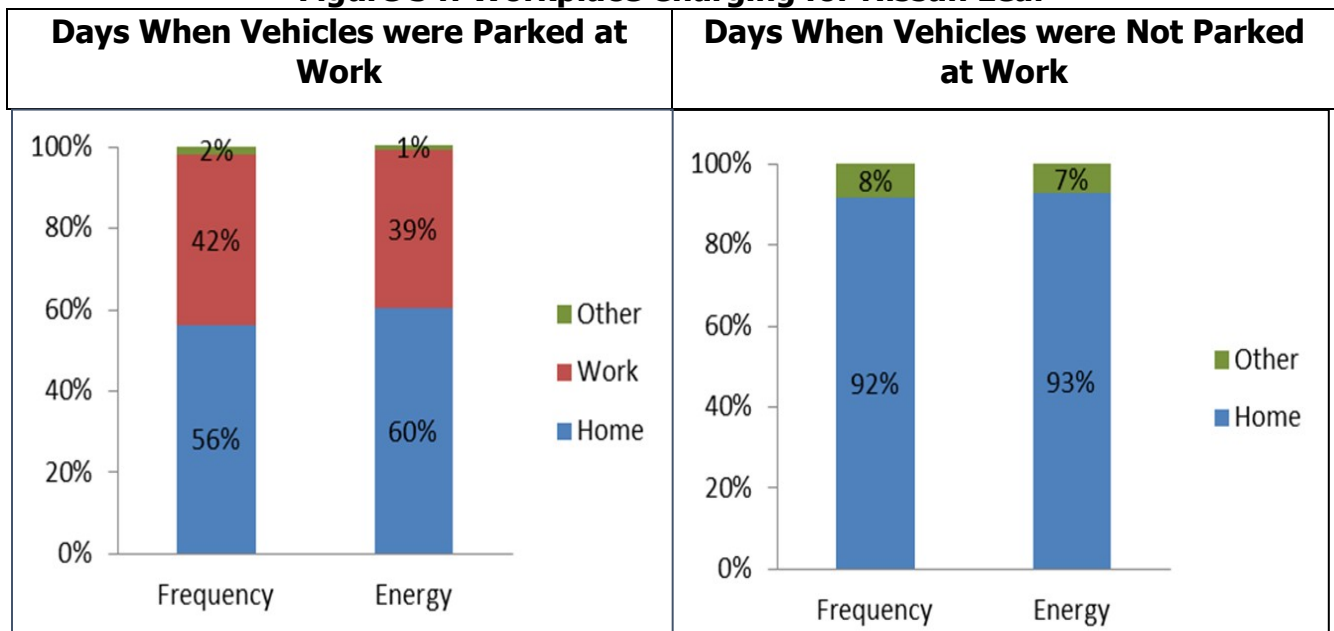
Source: Idaho National Laboratory

Those who charged in the workplace charged away from home more than twice as much as the overall project group and most of that away-from-home charging was at work. This was a national study and the specifics of the San Diego region are not available. However, it is clear that the shift in charging from the home to the workplace will have an effect on the electric utility grid.

For the group of 707 Nissan Leafs with access to workplace charging, a difference exists in their charging behavior between when they park at work and when not. Figure 54 illustrates this difference.

¹² [Where do Nissan Leaf Drivers in the EV Project Charge when they have the Opportunity to Charge at Work?](https://avt.inl.gov/sites/default/files/pdf/EVProj/ChargingLocation-WorkplaceLeafsMar2014.pdf)
<https://avt.inl.gov/sites/default/files/pdf/EVProj/ChargingLocation-WorkplaceLeafsMar2014.pdf>
 [Accessed April 10,2014]

Figure 54: Workplace Charging for Nissan Leaf

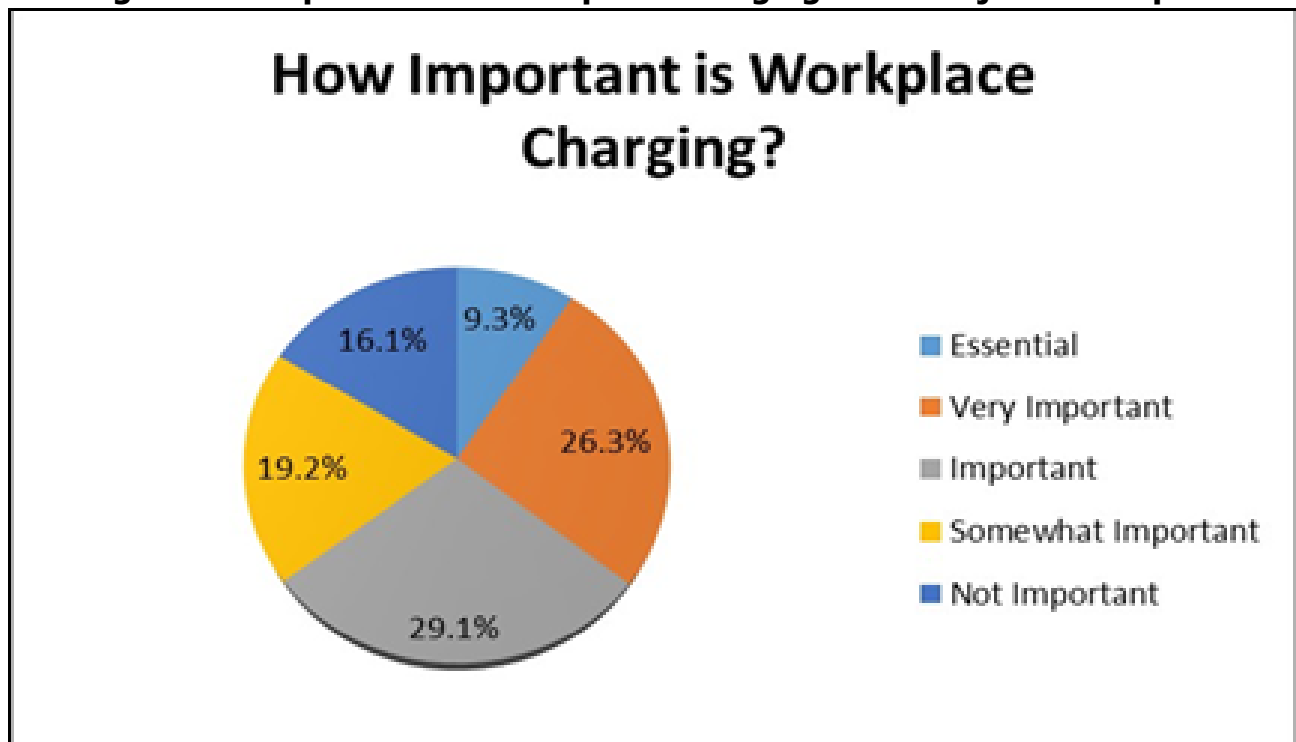


Source: Idaho National Laboratory

Drivers who parked at work had little use for public infrastructure on those days.

The importance of workplace charging was part of the larger survey noted above. For those respondents who had access to workplace charging, 55.4 percent report workplace charging is either very important or essential to their charging needs. Figure 55 shows the breakdown of workplace importance for those with access.

Figure 55: Importance of Workplace Charging to EV Project Participant



Source: Blink Network

Grid Impact of Residential Charging

The change in transportation fuel from petroleum products to electricity as the PEV transportation segment grows will certainly impact the demand for electrical power. The impact is in the time energy profile of the charge and the magnitude of the energy charge.

The next section explores the influence of time-of-use rates in adjusting the time of this impact based upon the electric utility's needs.

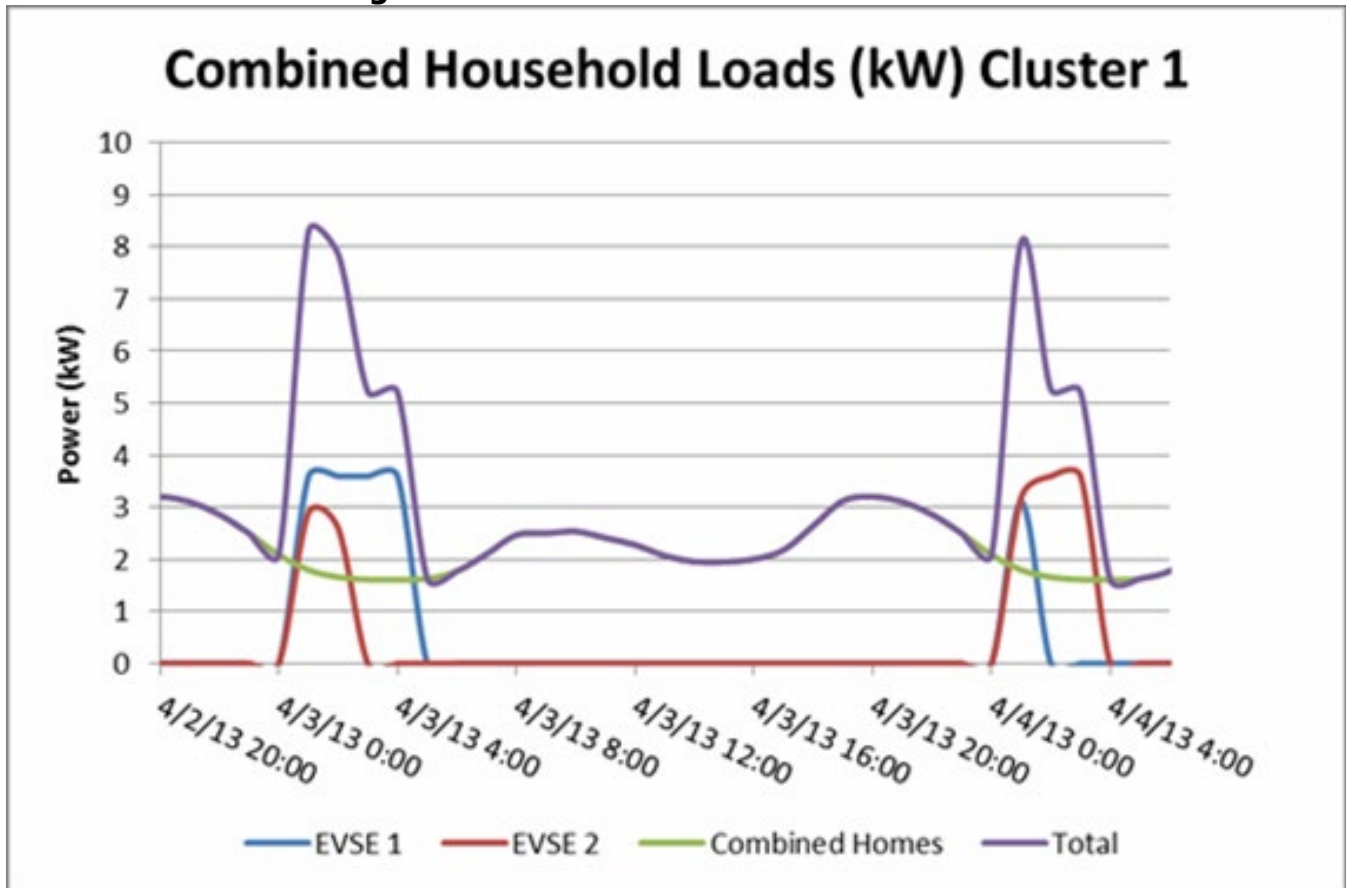
While the quantity of PEVs in a service territory is a clear influence on the charging impact, "clustering" may pose another impact.

OEMs understand that one promoter of vehicle sales is the visibility of a new car in a neighbor's driveway. Neighbors are often curious and interested in the new vehicle, especially if it is a new type of vehicle, such as a PEV. "Clustering" occurs when several PEVs show up in the same neighborhood and where those residences receive power from the same electrical transformer. While the transformer may be able to accept the power, demand increase from one PEV, multiple PEVs charging may cause damage to the transformer, resulting in a service outage and the need to upgrade that transformer. This damage may occur by overloading the rating of the transformer or by depriving the transformer of its normal cool-down period, typically found in the early morning hours.

The project reviewed this topic in the report: "Clustering Effects that have been seen by the EV Project?" It found several locations of potential clustering in the San Francisco Bay Area. While the project does not have access to utility records of houses served by individual transformers, the proximity of several participants resulted in the likely scenario that clustering occurred.

Using actual charge records of the participants, three sites were examined. In the first site, two nearby residences owners programmed the start of the charge to occur off-peak and both initiated the charge directly at midnight. When combined with the typical household loads, Figure 56 shows the resulting charging load.

Figure 56: Combined Loads Cluster Site 1

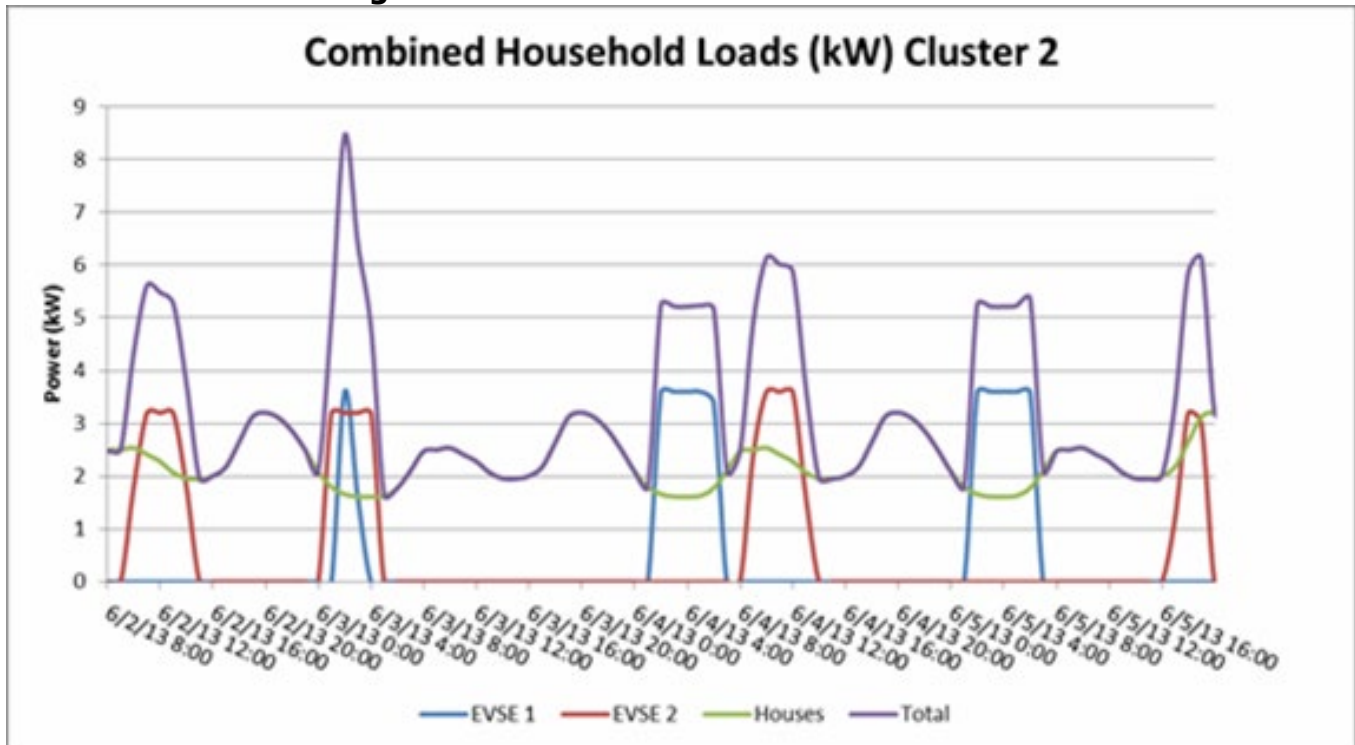


Source: Blink Network

Not only do the peaks occur at midnight but the neighborhood transformer provides almost four times the energy from midnight to 4 a.m. than would be provided without the charging.

Cluster site 2 involved one residence which started the charge at 1 a.m. The second residence charged at 1 a.m. but also at other times of the day. When combined with typical household loads, the load demand is as shown in Figure 57.

Figure 57: Combined Loads Cluster Site 2

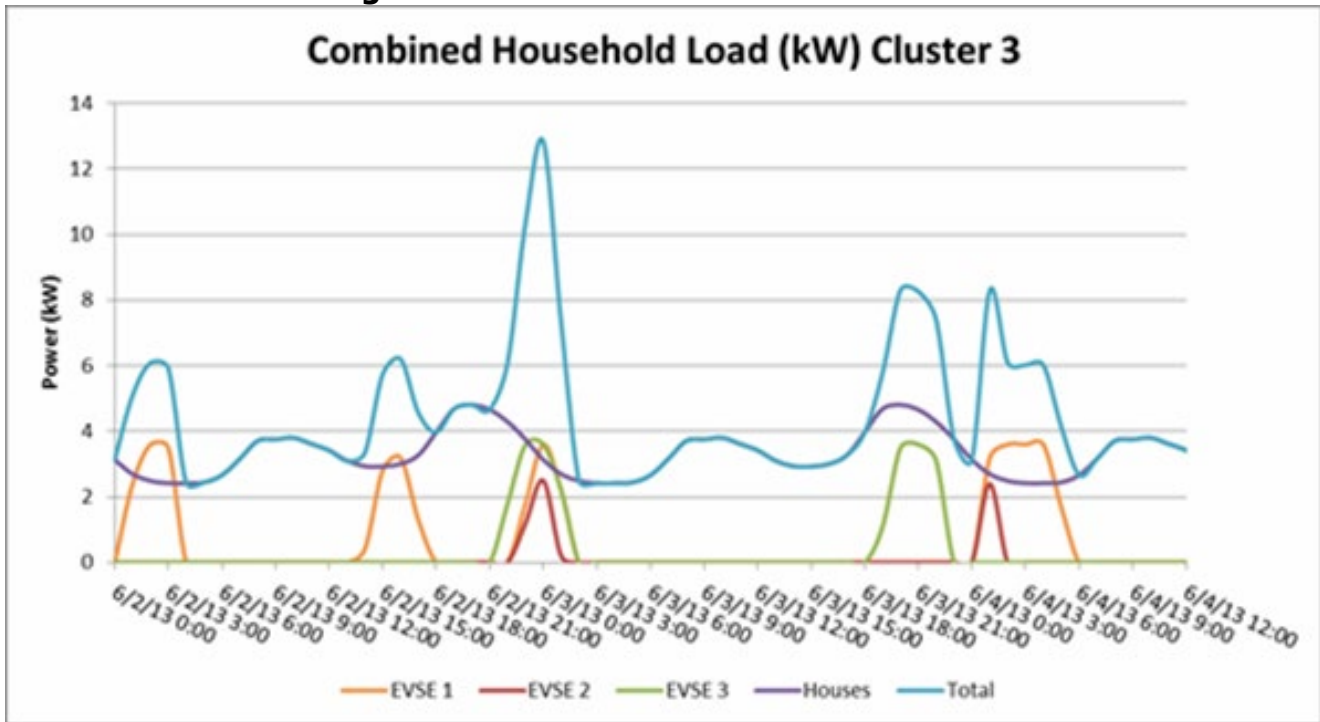


Source: Blink Network

The PEV charging causes three separate effects on the local transformer. The peak caused by simultaneous charging occurs as before. The early morning of June 4 shows the sequential charging peaks during the time when electric utilities anticipate lowest residential demand. This negates the anticipated overnight cool-down time for the transformer. Finally, other morning charging in House 2, as shown on June 2 and June 5, adds peaks in the daytime that also can affect transformer cool-down during other typically lower demand times.

Cluster site 3 had three neighbors in close proximity. Through a combination of programming and random charge events, the combined load is as shown in Figure 58.

Figure 58: Combined Loads Cluster Site 3



Source: Blink Network

The total energy increase through the transformer for the three days of June was 69.3 kWh - an increase of 28 percent. The impacts of higher peak power demand (four times normal) and lack of cool down periods due to coincident and non-coincident charge events, could be stressing the neighborhood transformer.

All the PEVs in the above examples have chargers capable of charging power at up to 3.3 kW. Newer vehicles provide chargers capable of 6.6 kW or higher which magnifies the potential problem. While no cluster sites in the San Diego region were studied, similar conclusions apply. Some suggestions for mitigation involving smart EVSE, off-peak start times and end of charge programming as included in the paper.

Non-Residential ACL2 Deployment Observations

The away-from-home charging for participants is either at publicly available EVSE or workplace EVSE. The number of publicly accessible EVSE charge events shown in Figure 47 excludes the car-sharing events.

Public Charging Installation Costs

In general, the project planned the non-residential sites to include a minimum of two EVSE. This provided longer range planning for the site utilization while reducing the average installation cost per EVSE. The project budget provided some incentive to the host for these costs and generally allowed the installation at little or lower cost to the host.

The project conducted an analysis of the non-residential costs for all regions. At the time, the installation costs nationally ranged from \$358.79 to \$41,764.40 with an average of \$5,512.29 per site.

The San Diego area non-residential EVSE installation costs ranged from \$553 to \$41,687.28 with an average of \$9,329.62 per site. The highest cost installation included 42 EVSE at the site for a unit average of \$992 per EVSE. At the completion of the project, 552 EVSE installed in 170 locations provides an average of 3.2 EVSE units per site.

The high cost drivers of non-residential EVSE are:

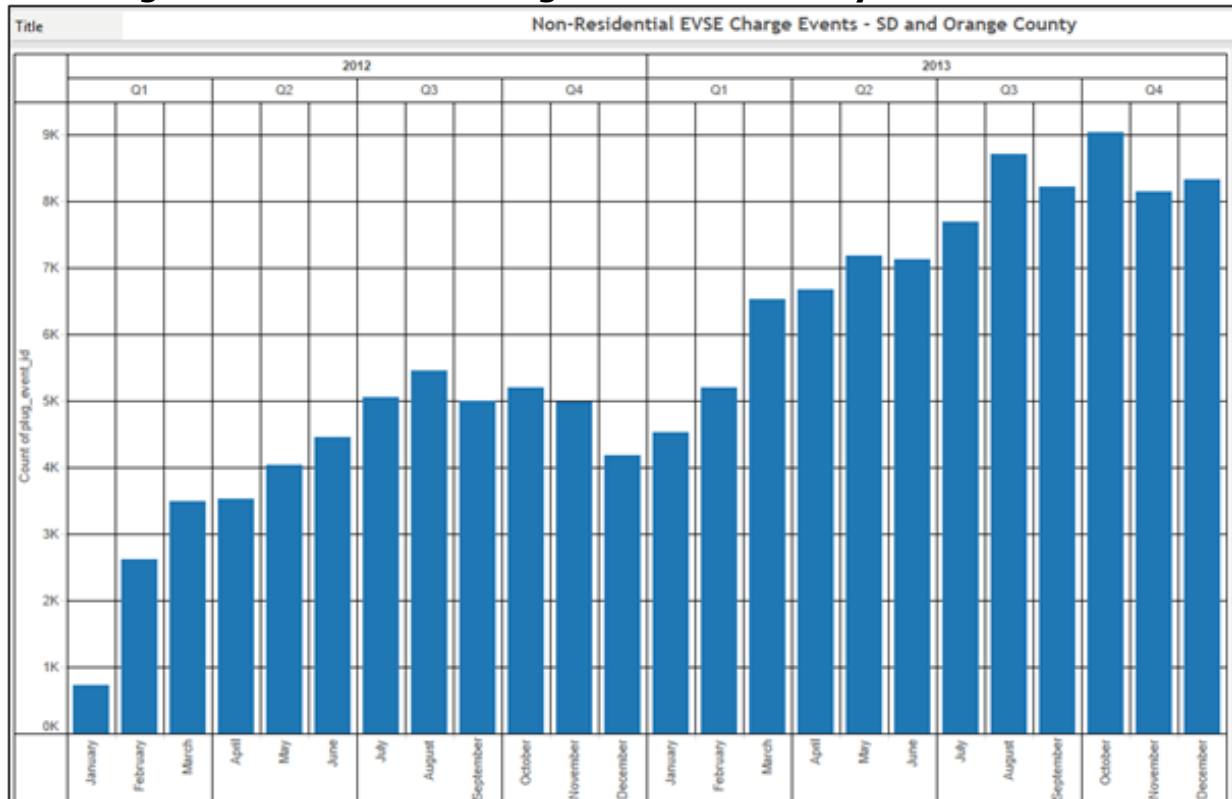
- Distance from the service panel (conduit run and conductor costs)
- Preferred location – host may desire EVSE in locations more difficult to install
- concrete, asphalt or other surface cuts and repairs
- compliance with ADA requirements
- engineered drawing requirements the low-cost drivers were:
- Easy installation where the conduit run is short, and a simple breaker addition was required
- Existing space near the breaker panel
- Using an existing ADA space and adjacent space to share an EVSE complying with ADA without impacting the other parking requirements

Part of the difference in installation costs is due to the cost of permits in San Diego County. Nationally, the permit fees ranged from \$14 to \$821 with an average of \$139. In San Diego County, the permits fees ranged from \$44 to \$821 with an average of \$361. The average is 2.5 times the national average.

Public Charging Events

The quarterly reports identify the number of publicly accessible charging events. Figure 59 shows these events for the entire project.

Figure 59: Number of Charge Events at Publicly Accessible EVSE



Source: Blink Network

The above figure shows the non-residential EVSE for both San Diego and Orange Counties. The Orange County EVSE units were added in the first half of 2013 and both counties show an increasing use of these non-residential EVSE.

The usage varies by day of the week as shown in Figure 60.

Figure 60: Non-Residential EVSE Connect Events by Weekday (Q4, 2013)

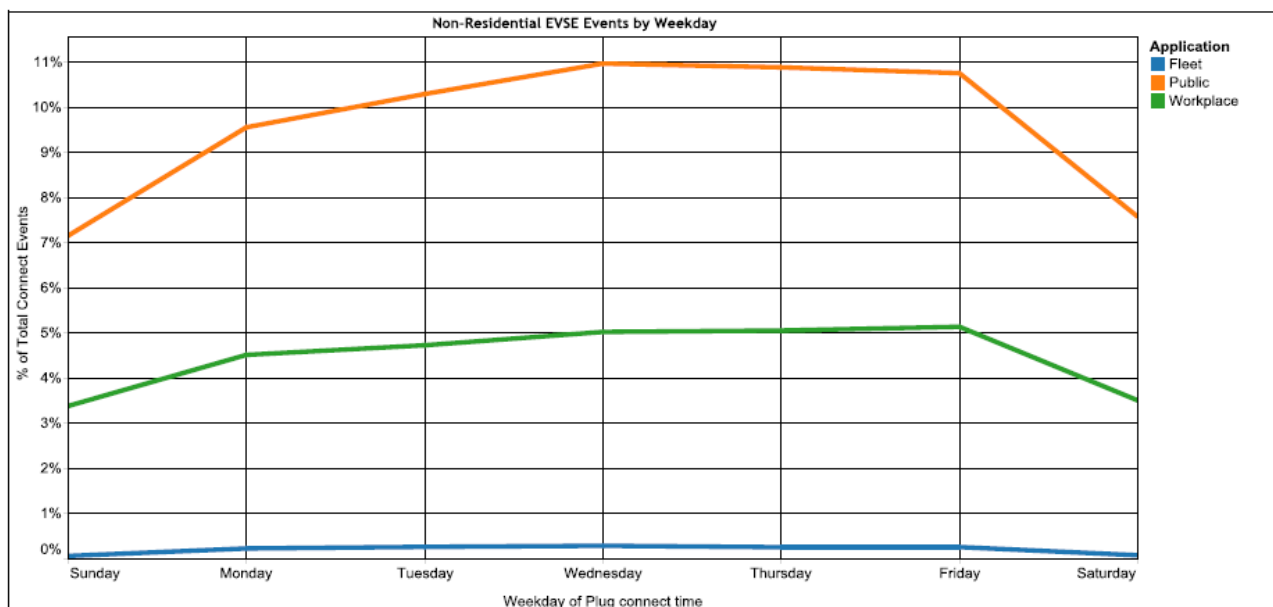


Photo Credit: Blink Network

The usage for public and workplace applications follows the same profile throughout the week while fleet usage displays constant use each day as might be expected.

Figure 61 shows the distribution of charge start times versus the time of the day.

Figure 61: Non-Residential EVSE Connect Events by Time of Day

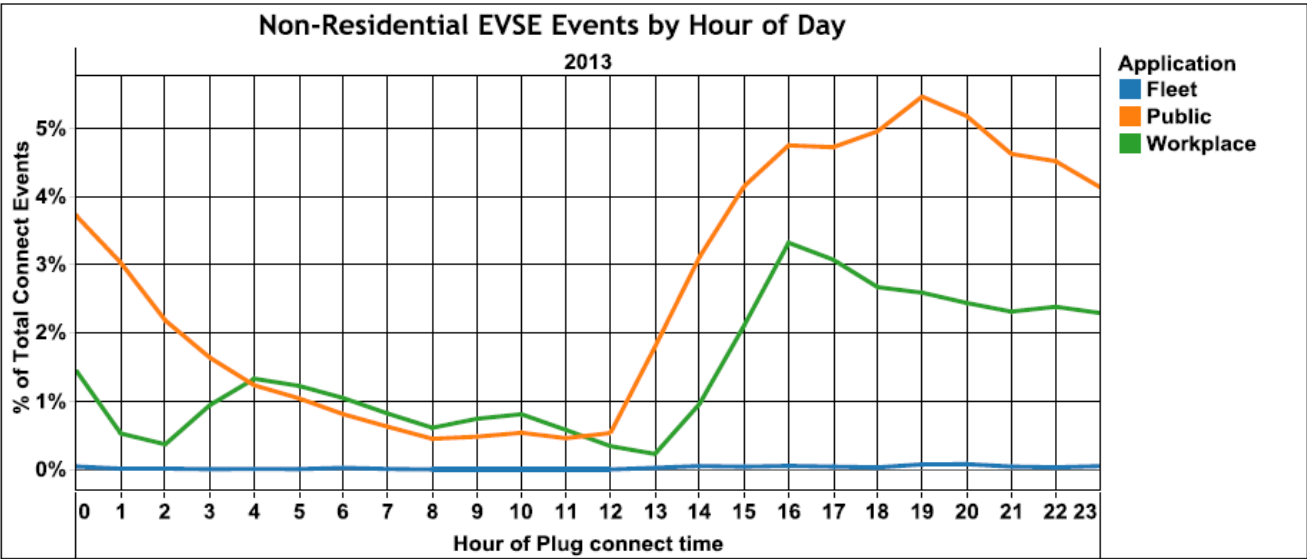
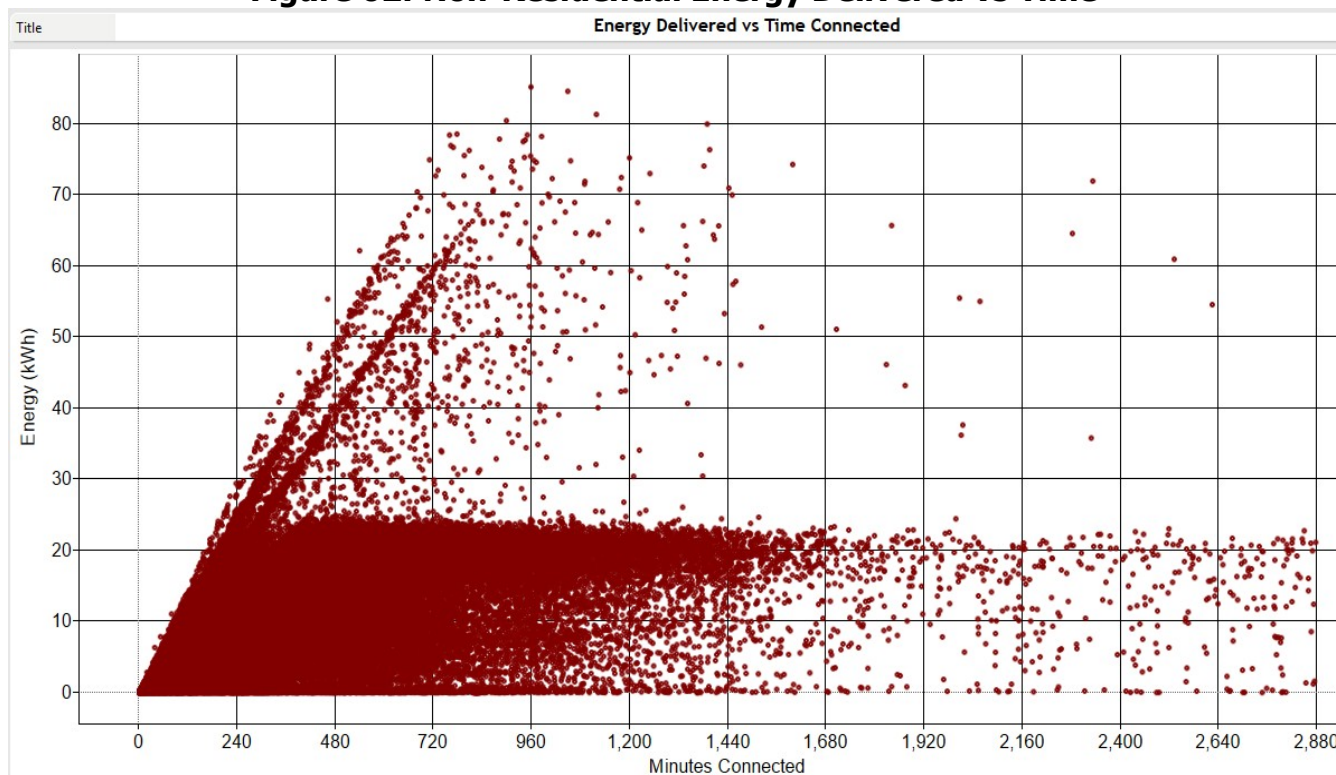


Photo Credit: Blink Network

It is noteworthy that all workplace EVSE in this study are AC Level 2 and some charging begins upon arrival at work at 4 a.m. and later but it is minimal compared to that which occurs in early afternoon and reaching a peak about 1600. It may reflect employees leaving the worksite to tend to errands or lunch and returning to commence the charge, or it may be a consistent start of a second wave of charging when morning charger users move at lunch. The morning charge would be expected to be less of an impact if the vehicle was fully charged at home that night.

Workplace charging overnight might reflect charging of the employer’s owned vehicles. Figure 62 shows the energy delivered vs time connected.

Figure 62: Non-Residential Energy Delivered vs Time

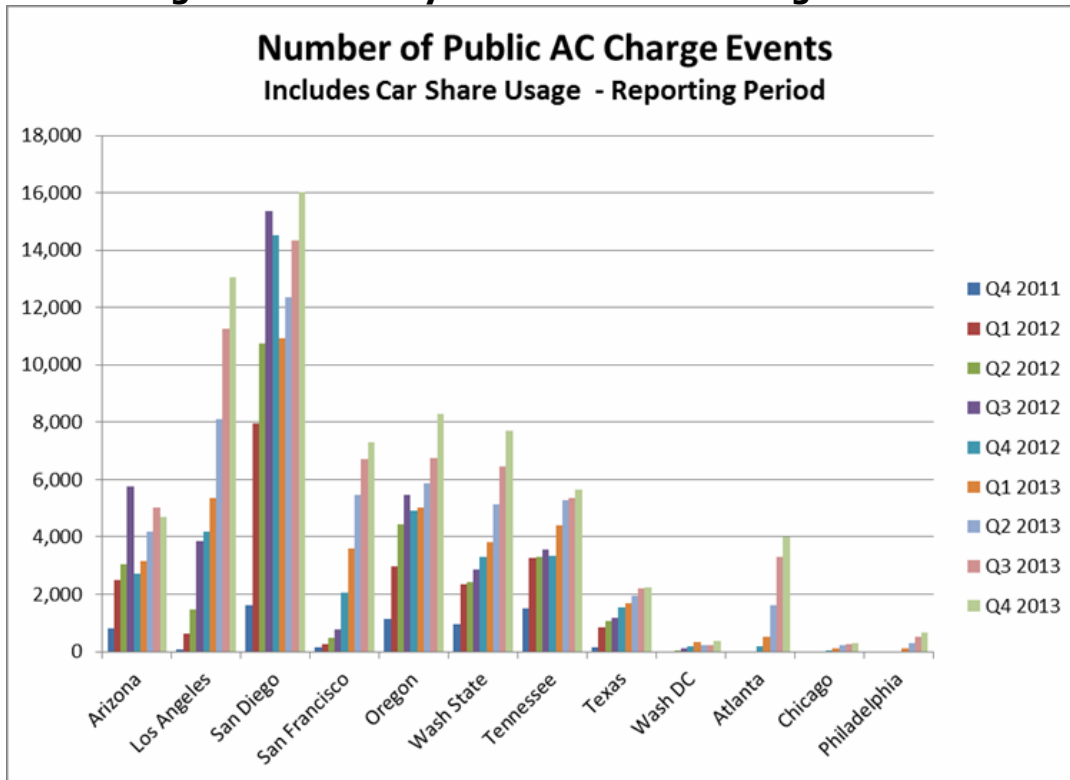


Source: Blink Network

The slope of the far-left curve is 7.2 kW/hr. The next distinct slope is about 6.0 kW/hr and the third is about 4.9 kW/hr. Because the Leaf has a maximum battery capacity of about 24 kWh, the scatter points above 24 kWh would be another vehicle. Sorting by workplace, fleet or public revealed very little difference from the overall plot.

Figure 63 shows the number of publicly accessible charge events in San Diego. This figure combined the fleet and workplace EVSE with the publicly accessible until the fourth quarter 2012. The car sharing program commenced using the publicly accessible EVSE in third quarter 2012. The following section explores the impact of the car sharing program in more detail.

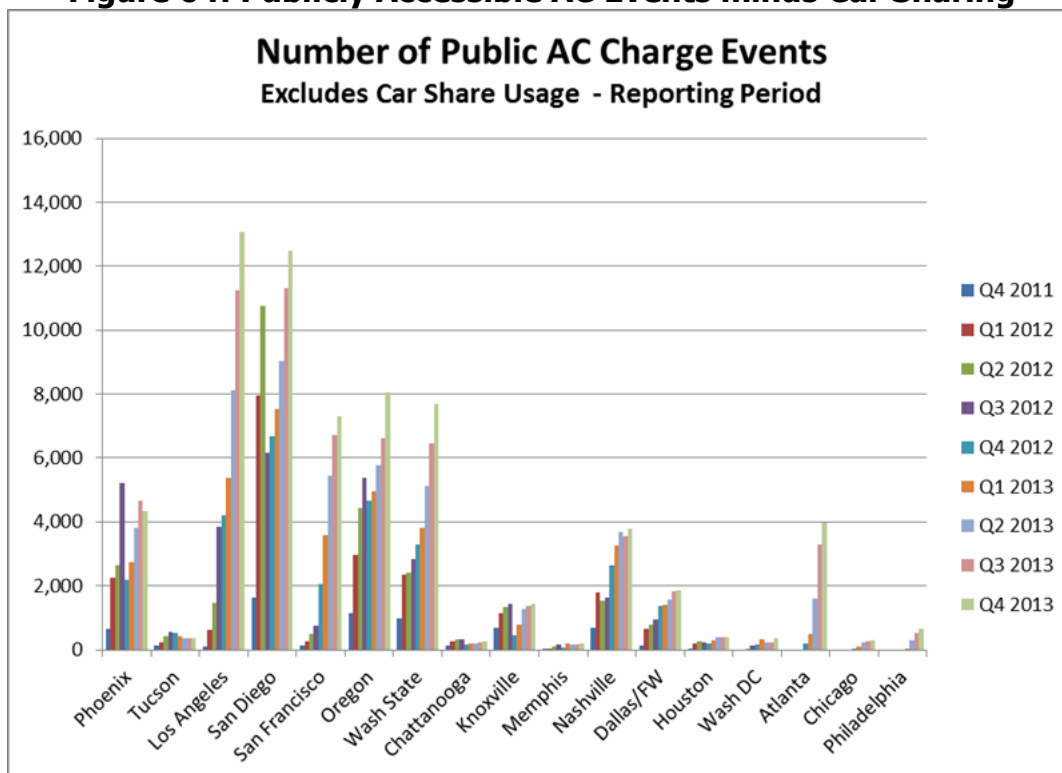
Figure 63: Publicly Accessible EVSE Charge Events



Source: Blink Network

Removing the car sharing events for San Diego resulted in the statistics shown in Figure 64.

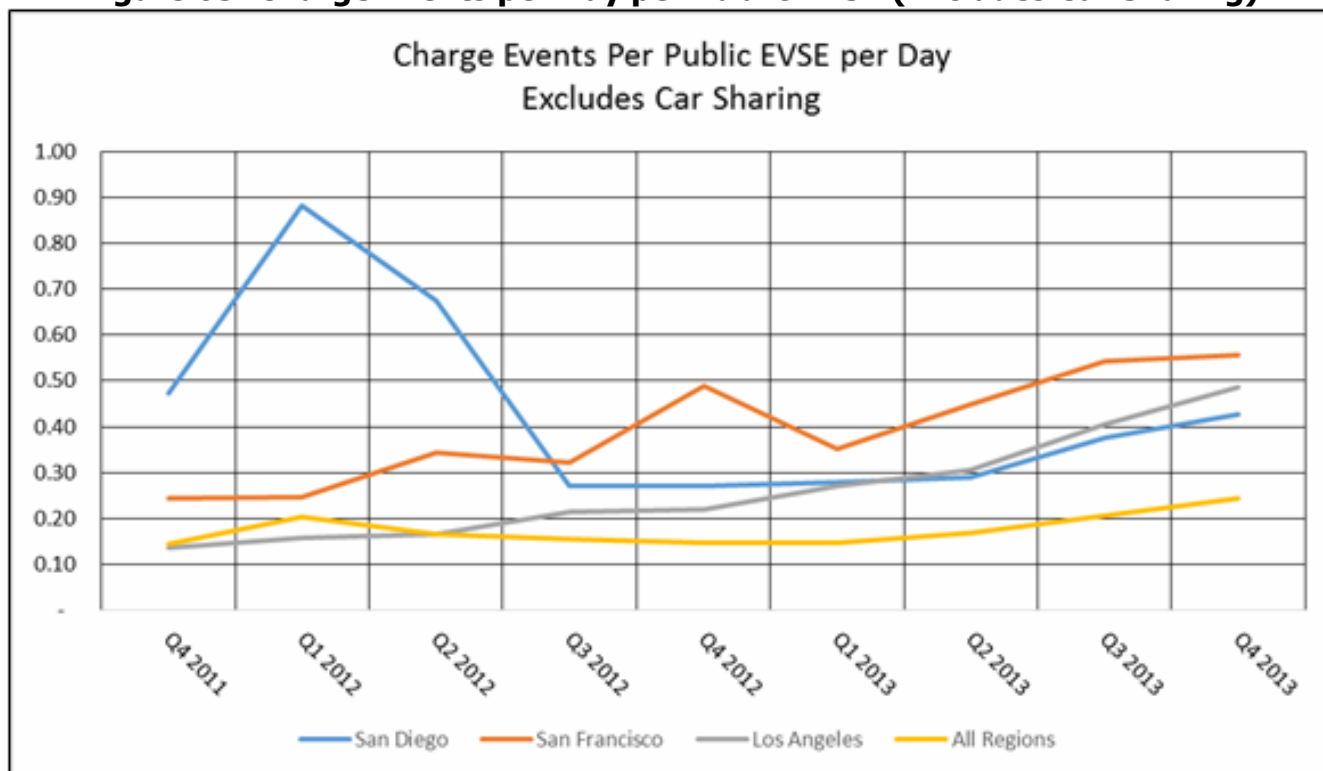
Figure 64: Publicly Accessible AC Events minus Car Sharing



Source: Blink Network

Putting this more in context with the number of public chargers available results in Figure 65.

Figure 65: Charge Events per Day per Public EVSE (Excludes Car Sharing)



Source: Blink Network

At almost double the national average, San Diego drivers show exceptional use of the public infrastructure provided by the project. Figure 66 also shows the exceptional use of public infrastructure in the Los Angeles and San Francisco areas: both of which are also greater than the national average and even greater than that of San Diego.

Utilization of Public AC Level 2 Charging

The EV Project collected usage data over 4 million charge events nationally and over 660,000 charge events in the San Diego region. While some are residential, workplace or fleet applications, one of the primary goals of the EV Project was to study the location and use of publicly accessible infrastructure. Consequently, installation of the majority of these non-residential EVSE units occurred near shopping malls, business offices, retail locations and other sites commonly accessed by PEV drivers. A frequently asked question relates to which venues or locations are the best for charge opportunities. This is of interest to governmental officials, EVSE suppliers, infrastructure planners, charging site hosts, OEMs and PEV drivers. If there is a limited budget to support PEV charging infrastructure, where should the EVSE be placed?

The EV Project found that there can be many definitions for “best” because there are many reasons why charging site hosts desire providing charging infrastructure at their facility. Some may be supporting this industry for its GHG reductions, the reduction in petroleum usage or public image may be important. Others may be looking for the business advantages that may occur in attracting the PEV drivers, or maybe they just want to be providing leading edge technology. In the view of the EV Project, there are no poor choices for sites for publicly

accessible infrastructure because every installation tells a story and observations develop from its use, or lack thereof. Poor locations are those where data indicates the choice did not meet the hosts' expectations.

One prime example discovered through the EV Project was a city's decision to place the AC Level 2 at an intermodal parking area. The decision originated with the strong desire to promote the park and ride nature of the location and the developing promotion of public transportation. However, that particular unit would likely charge a single PEV in the day and that for only the first few minutes of the day. Park and ride locations are typically closer to the residence so PEVs may not need the charge at all, if indeed a PEV owner would utilize the location. From a high utilization perspective, the location may be poor but from the political perspective, it may be an excellent location.

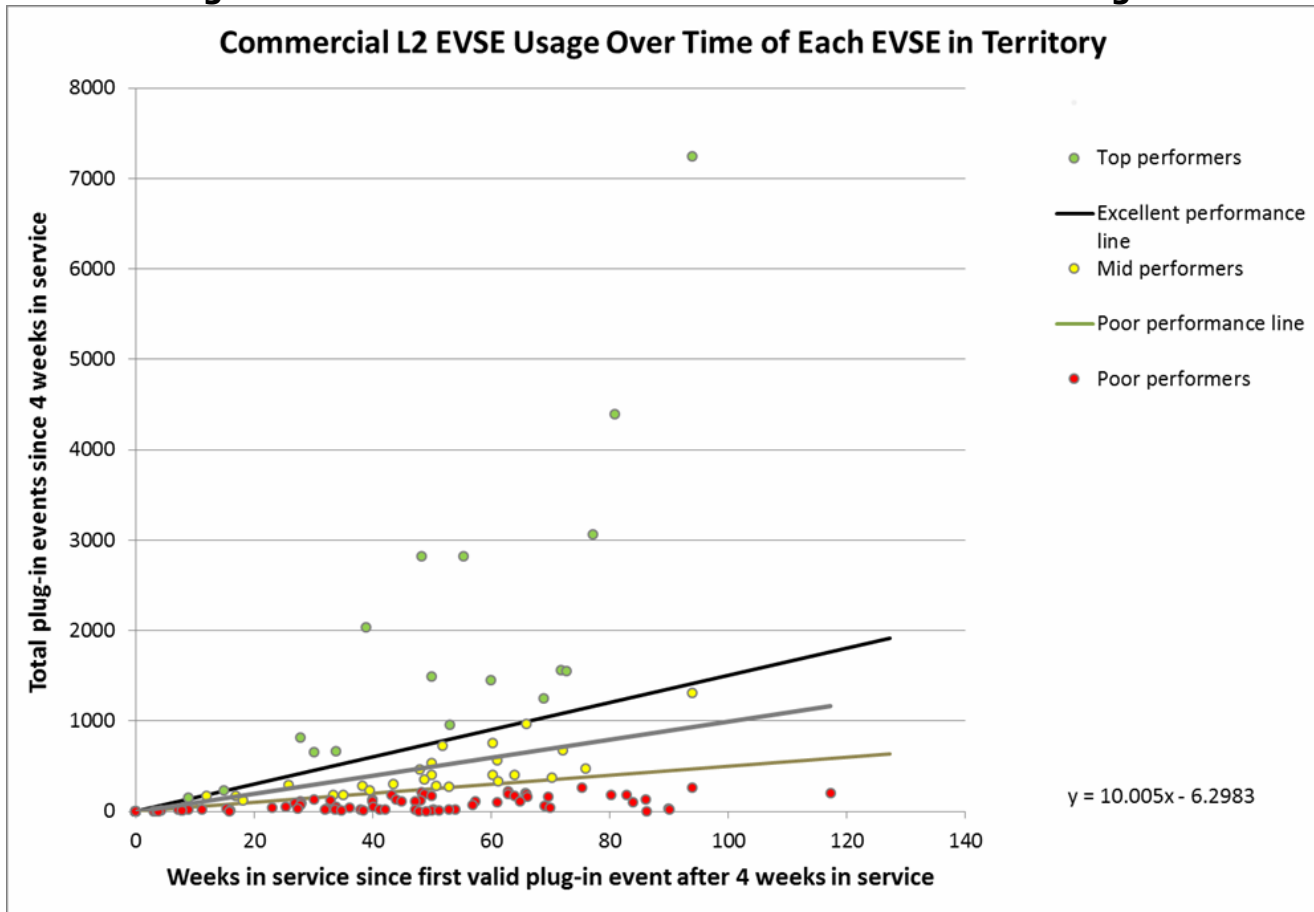
The EV Project was also tasked with evaluating revenue models for charging site hosts and EVSE suppliers. Thus, a fee for public charging and high usage of the installed EVSE is important. The metric selected for evaluating the utilization then is the average number of connect events per week from the time of the EVSE's installation. A "connect event" is defined as plugging the EVSE connector into the PEV charge port, after which some power transfer actually occurred. Most public locations in The EV Project installed more than one EVSE unit which improves installation cost effectiveness and provides for demand growth. Because all installed EVSE units contribute to the site's utilization, the connect events for all units at a site were summed. Finally, the public requires some time to recognize a new deployed EVSE in a particular location. The data excludes the first four weeks following an individual EVSE installation.

In the San Diego region, the evaluation of utilization involved 432 publicly accessible EVSE at 135 different sites. Figure 66 shows the results of this evaluation in San Diego.

Each dot in the figure represents a single site that may contain several accessible EVSE. The trend line of approximately 10 charge events per EVSE per week indicates the average utilization summing all EVSE usage at each site.

The evaluation of whether a particular site is a top, average or poor location then is a relative assessment based upon the characteristics of the region. In San Diego, the Top Performer line above occurs at 15 charge events per week per site and the poor performance line occurs at five charge events per week per site.

Figure 66: Commercial AC Level 2 EVSE Utilization San Diego



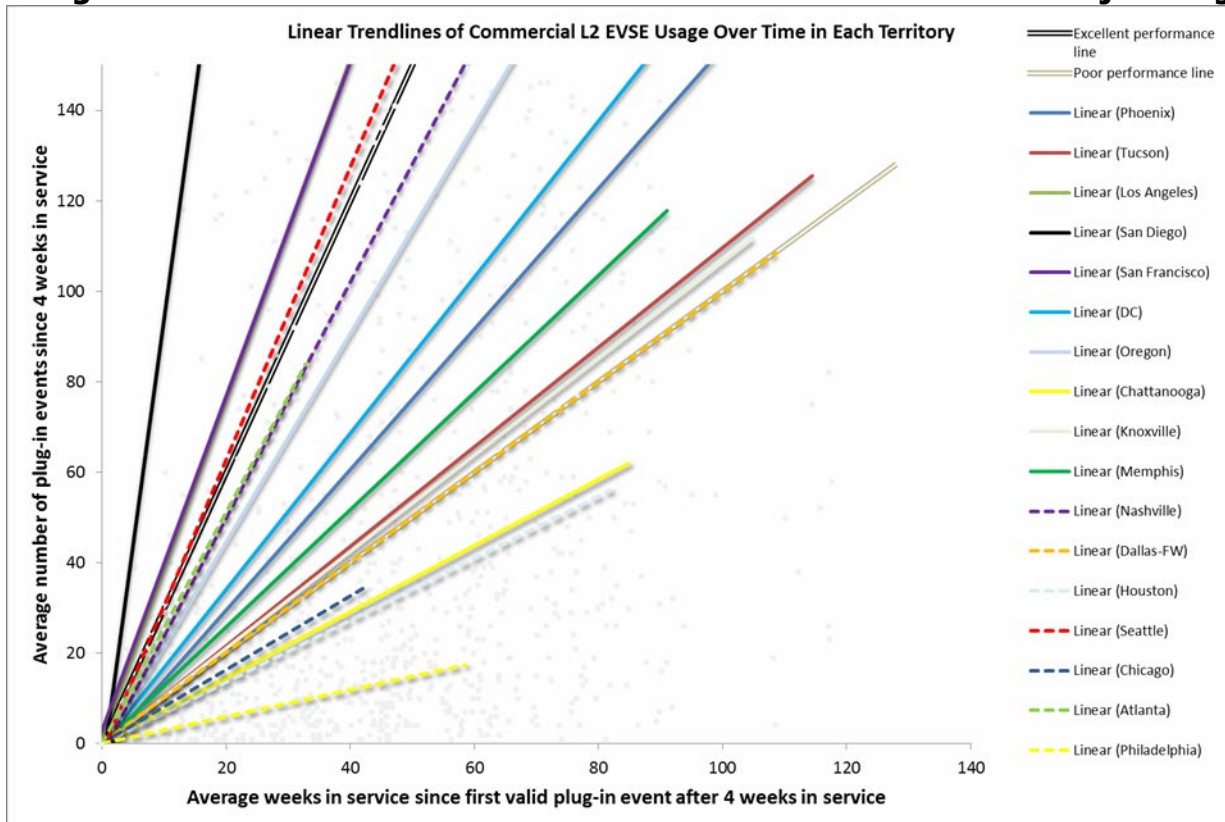
Source: Blink Network

How does this compare to the other EV Project regions? Figure 68 provides the EV Project national evaluation by region.

Figure 68 shows the exceptional overall usage of the public EVSE in the San Diego region followed by the Los Angeles region at 3.8 events per week per site and San Francisco region at 3.7 events per week per site. San Diego EVSEs are by far the most utilized EVSE in the EV Project. The national trend line occurs at just over two charge events per site per week. With this perspective, the top performers in San Diego are truly the project top performers. For regional comparisons, the top performance line in Figure 67 is set at three charge events per week per site.

While it might appear that the advantage for high performance goes to the site with the most EVSE, such is not the case. Since the ranking is by site, a particular site may have one EVSE that is highly utilized (because it may be closer to the facility entrance) and other EVSE that are rarely used. A first look at utilization in this manner found many sites having EVSE both in the top and poor performance categories.

Figure 67: Utilization Trend Lines for Commercial L2 for All EV Project Regions



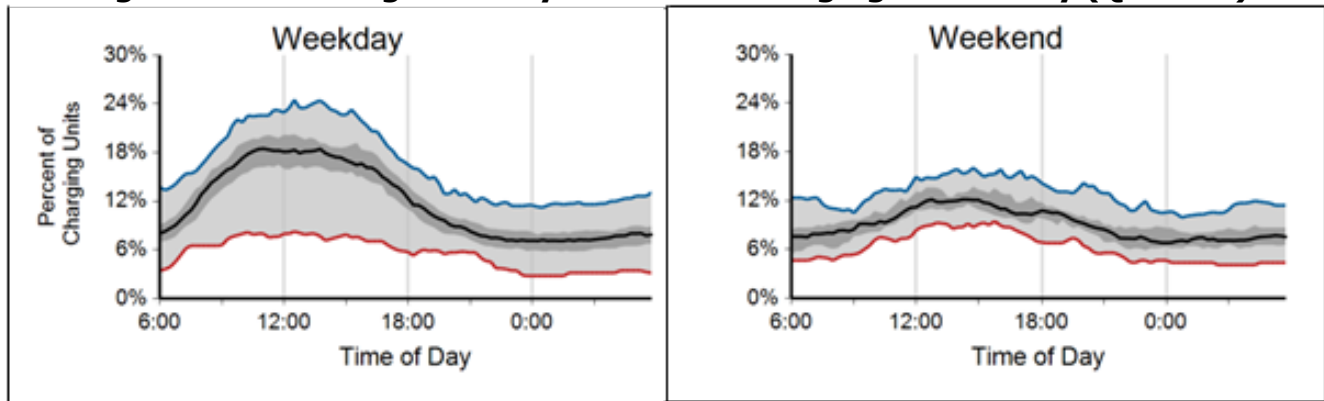
Source: Blink Network

Further analysis of the top and poor performers is desirable to identify the site venue and geographic location. This analysis was in process at the time of the EV Project bankruptcy. Each site was being categorized by application (workplace, fleet, public), by venue type (22 different categories) and environment (urban, suburban, corridor, industrial). At this point, the top performer in the San Diego region in terms of high utilization is at Balboa Park near the Air and Space Museum with an average of more than 189 events per week among the area's seven EVSE.

Grid Impact of Public AC Level 2 Charging

The use of publicly accessible EVSE has impact on the electric grid. Time-of-day plots provide the best illustration of this using terms of Charging Availability: the percentage of charging units with a vehicle connected versus time of day and Charging Demand: the range of aggregate electricity demand versus time of day. Figure 68 shows these availability plots.

Figure 68: San Diego Publicly Accessible Charging Availability (Q4 2014)



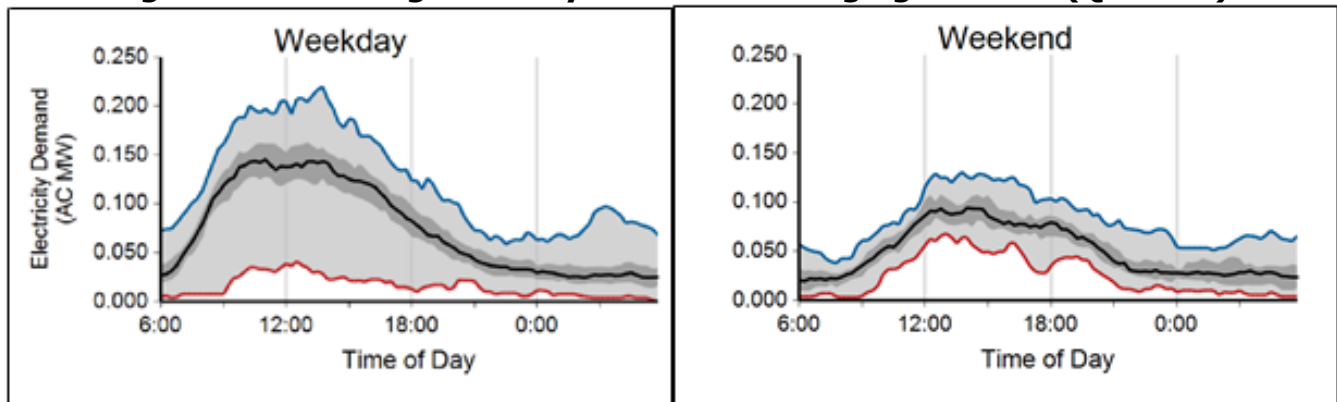
Source: Blink Network

These generally show the times of day when vehicles connect to these EVSE. They are generated by overlaying the daily connected curves for the entire quarter. The black line represents the median value for the quarter; the red line is the minimum for any time in the quarter; the blue line is the maximum percent connected in the quarter. The inner quartile is shaded dark gray.

Most use of publicly accessible charging is during the normal work/shopping times of the day. On an average day, approximately 18 percent of the publicly accessible EVSE will be charging a vehicle at noon. At all times in the quarter, at least 6 percent of the EVSE were connected to a vehicle and the highest number of EVSE connected in the quarter at noon was about 24 percent. They exhibit lower usage on the weekend as also noted above.

When connected, charging places a demand on the electric grid. A time-of-day plot again best shows the effect with the same features as noted above. For San Diego, Figure 69 shows this demand by time of day.

Figure 69: San Diego Publicly Accessible Charging Demand (Q4 2014)



Source: Blink Network

The peak in publicly accessible EVSE occurs during the daytime hours when peak power concerns apply. The demand placed on the grid by these EVSE added to the already stressed electric grid. Appendix V provides the lessons learned document with more detail on the methodology and an early look at the impact of EV charging on the grid.

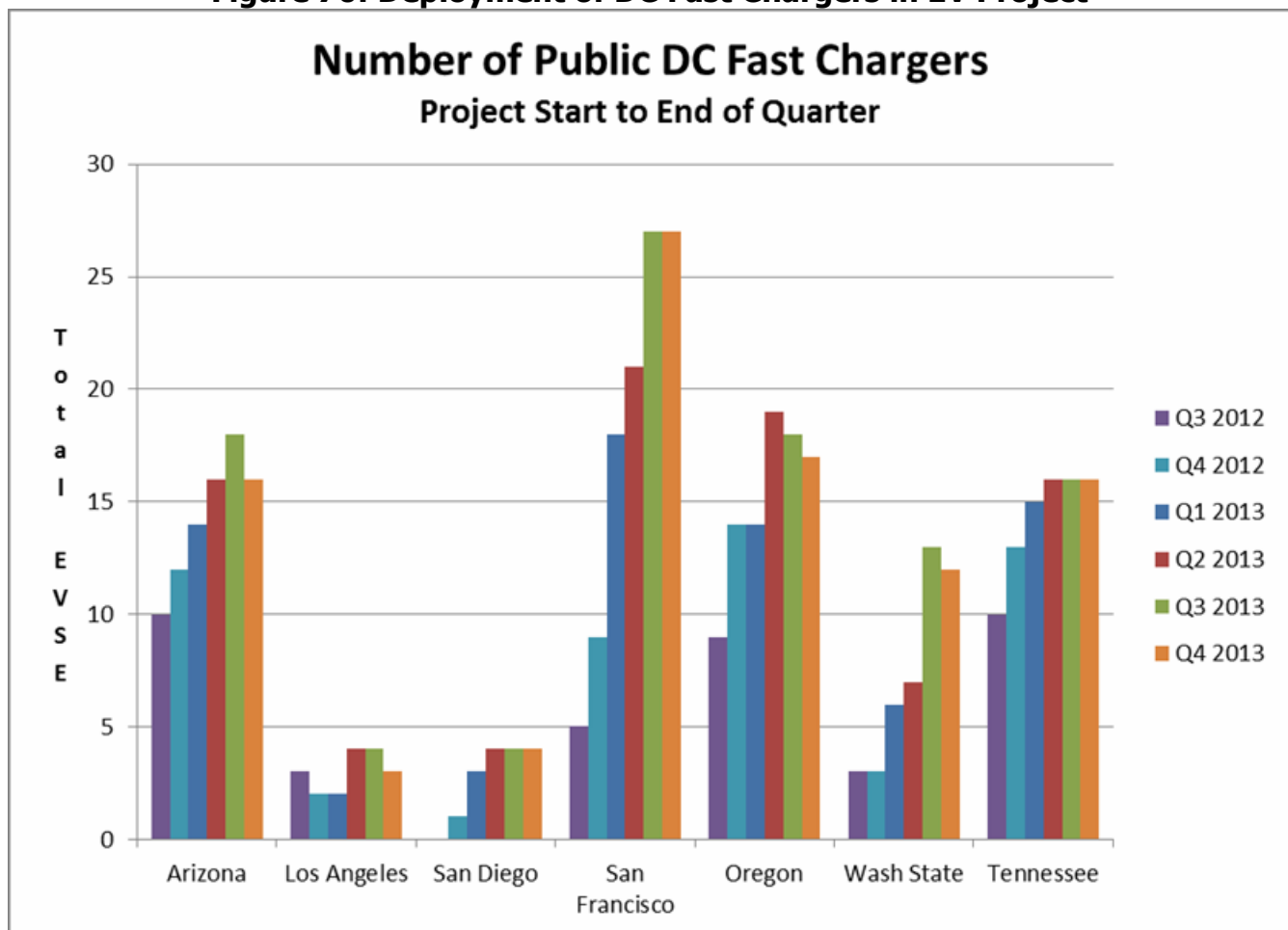
DCFC Deployment Observations

While the process was similar to non-residential deployment, the deployment of DCFC was an extremely time consuming and difficult task. The high-power requirements compounded the complex contract requirements for charging site hosts. The site installation costs were considerable higher requiring more resource incentives from the project. The electric utility demand charge on usage was another complication requiring more complex rules related to cost responsibility. The asset value of the DCFC was such that the US DOE retained rights to the DCFC equipment beyond the project completion date. DCFC ownership was then not available as a hosting incentive to the charging site host.

The Blink DCFC design addressed some of the ADA requirements by providing two charge ports. With two charge ports, only one could be ADA compliant while the other could be in a non-ADA required parking location. Otherwise, two separate units would be required resulting in increased costs. In addition, San Diego County required that an ADA compliant AC Level 2 unit be installed near the DCFC ensuring that ADA compliant PEV charging was available.

Deployment of DCFC commenced mid-2012. Figure 70 shows a comparison of DCFC installation in the EV Project by region and time.

Figure 70: Deployment of DC Fast Chargers in EV Project



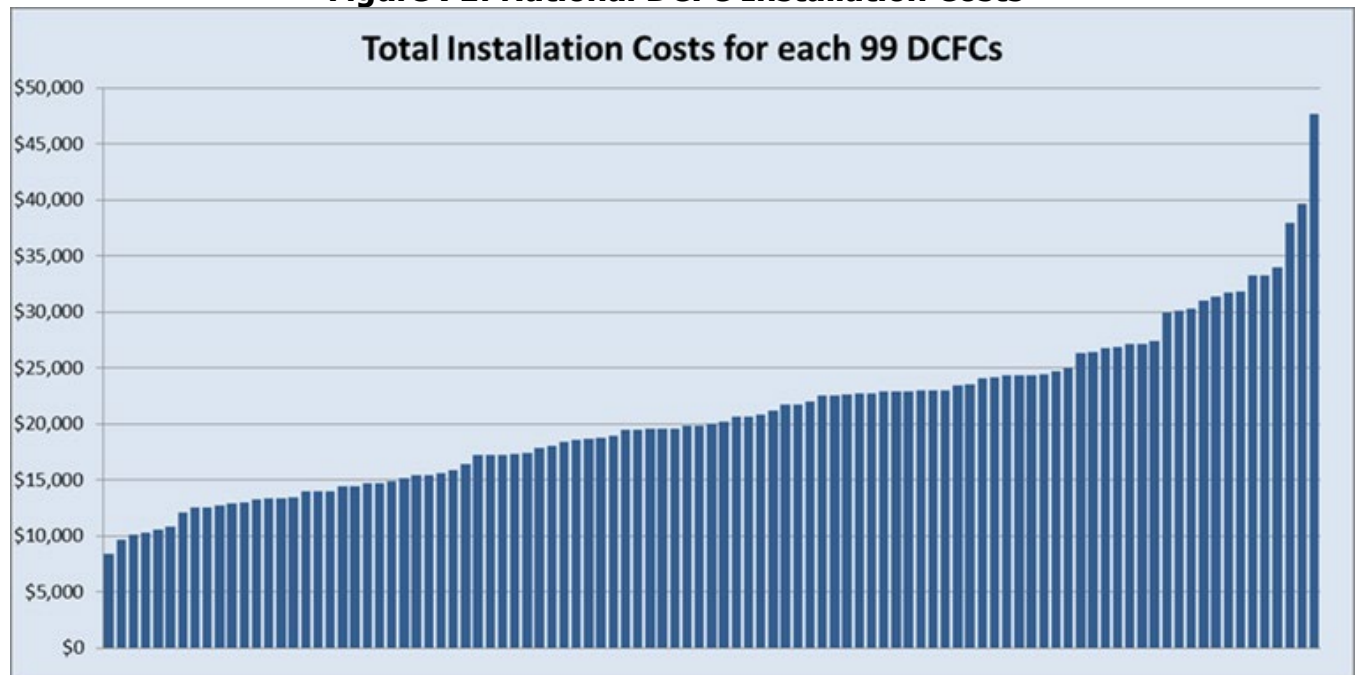
Source: Blink Network

As noted previously, only four DCFC were deployed in the San Diego area during the project execution period that this report covers (15 April 2011 through 31 December 2013). Much of the following information comes from the overall EV Project data and can be applied in part to San Diego and other regions. Where known differences occur, they are noted, and the impact identified.

DCFC Installation Costs

The project conducted an analysis of the installation costs for DCFC deployed in the EV Project. Without consideration of DCFC unit costs, Figure 71 displays the range of DCFC installation costs for all project units.

Figure 71: National DCFC Installation Costs



Source: Blink Network

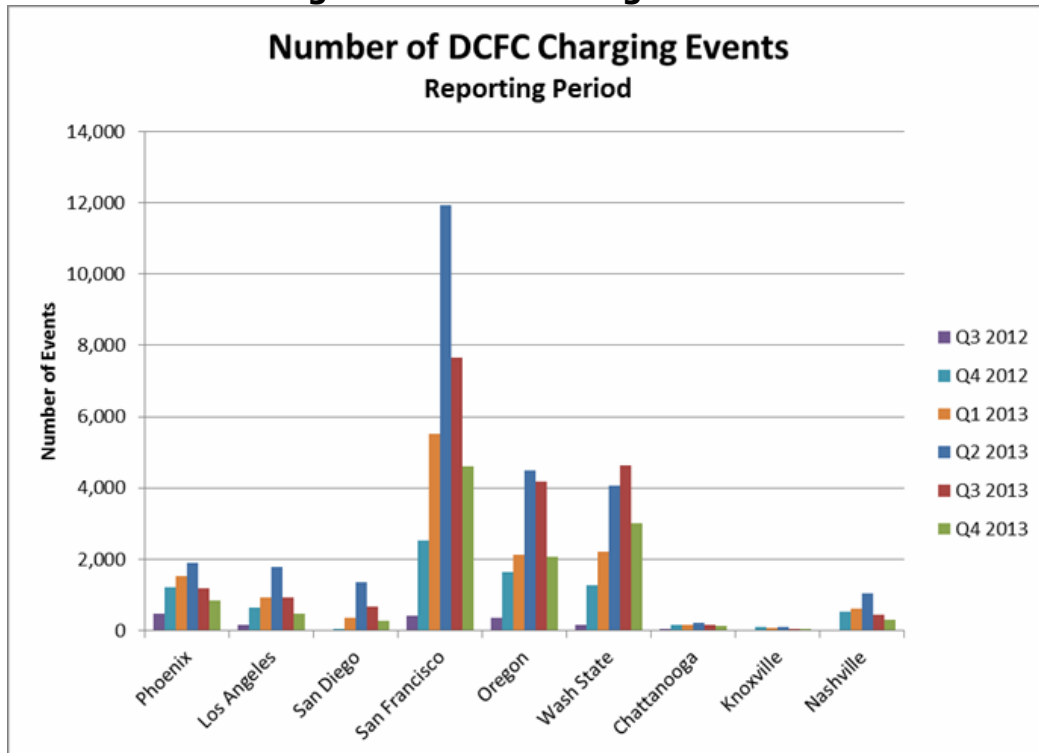
For these installations, the average cost is \$20,848.

For the four DCFC installed in the San Diego region, the cost varied from \$15,000 to \$27,100 with the average at \$23,025. As before, these do not include the cost of the DCFC. Also as mentioned earlier, the AHJs in San Diego County required an AC Level 2 EVSE be installed at the same site all DCFC. The San Diego region installation costs would reflect this additional cost.

DCFC Charging Events

The EV Project published a lessons learned document on the early experiences nationwide using DC Fast Chargers. Appendix W provides this report. This section provides a more focused look at DCFC use in the San Diego region. The quarterly reports provide information on the DCFC charging events. Figure 72 provides the events through fourth quarter 2013 for all regions of the project.

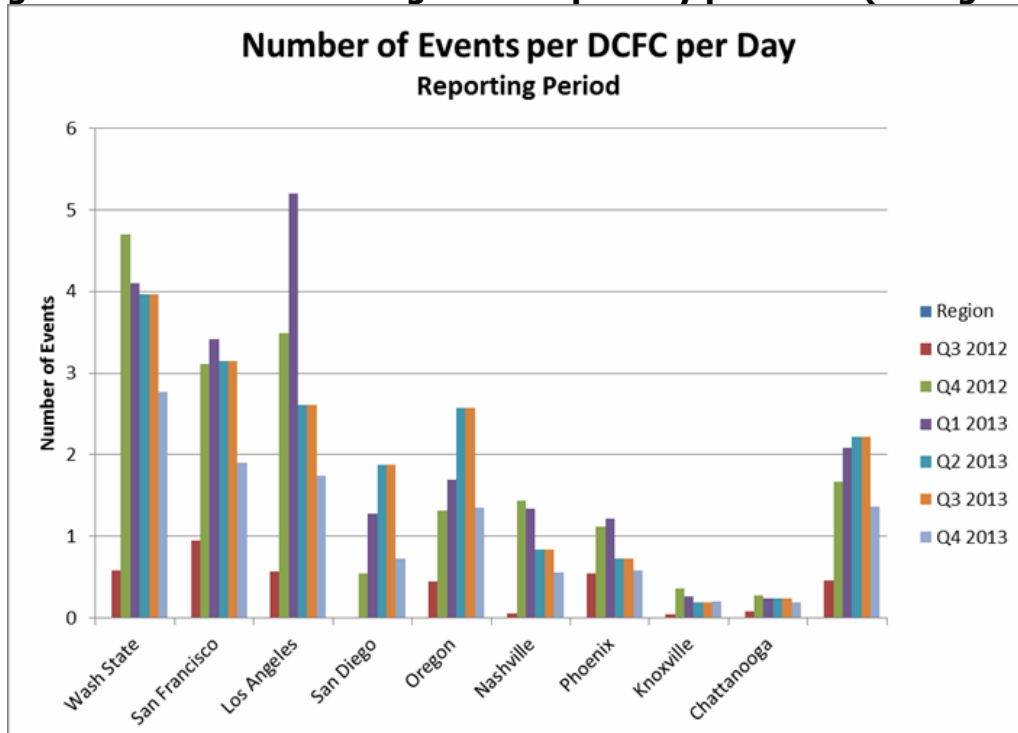
Figure 72: DCFC Charge Events



Source: Blink Network

Because of the large difference in quantities of DCFC in the regions of the EV Project, the average number of charge events per day per DCFC is an interesting comparison figure. Figure 73 illustrates this characteristic.

Figure 73: Number of Charge Events per Day per DCFC (all regions)

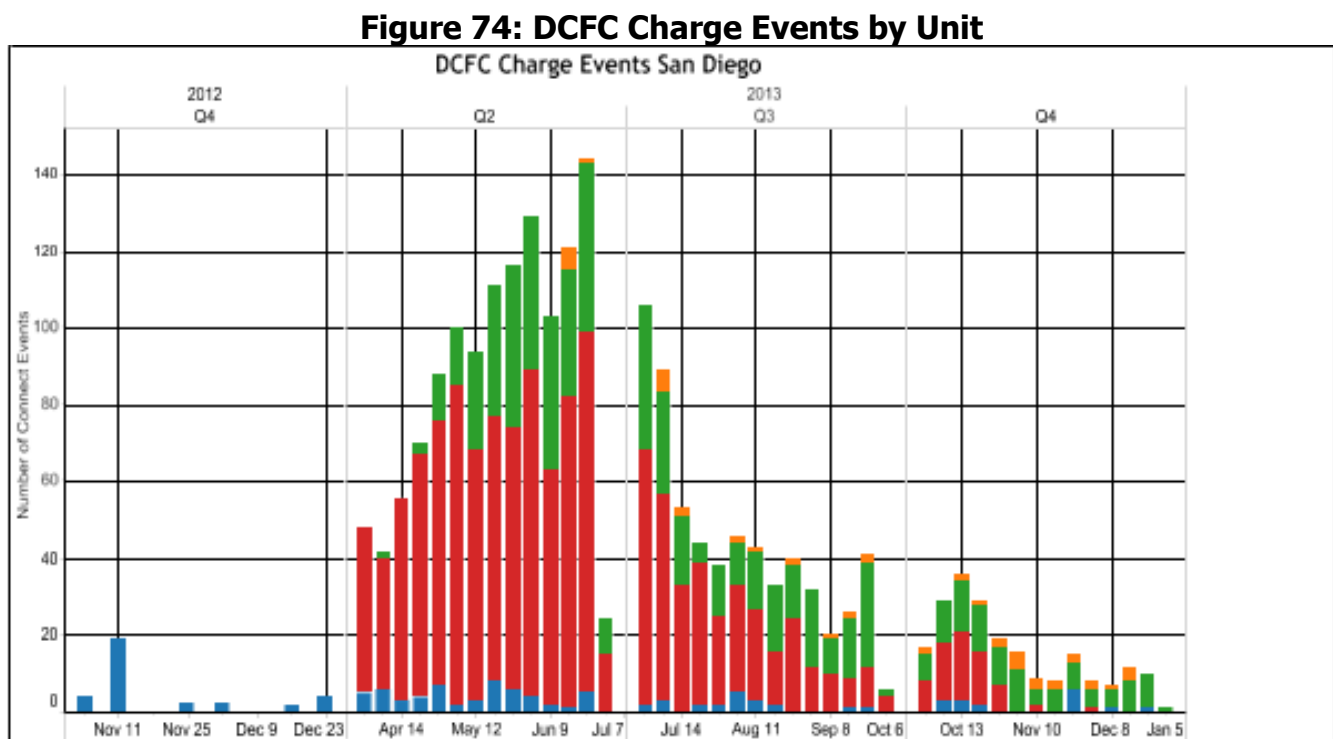


Source: Blink Network

Overall, there are 1.3 charge events per day per DCFC. The average time connected and drawing power is 24.6 minutes with an average of 9.3 kW energy consumed per charge event.

Because there are less than the minimum of 10 for aggregation per the EV Project, the quarterly report provides little information on the DCFC charging. Local analysis shows that the four DCFC in the San Diego area provide approximately 0.73 charge events per day per DCFC. The average connect time per event is 19.9 minutes. The average energy delivered per event is 9.1 kW.

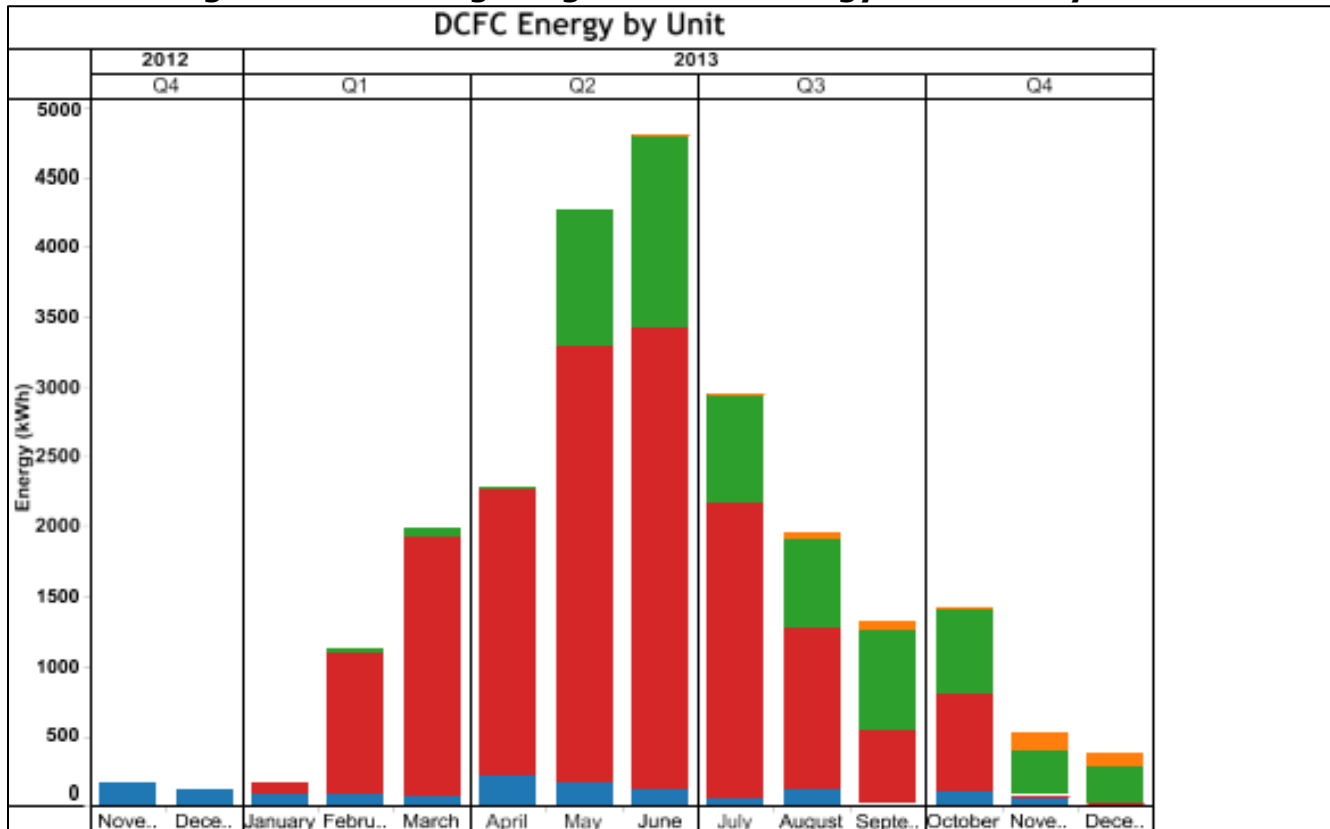
Figure 74 shows the usage of these DCFC. This shows the decline in usage of the DCFC from a high of about four connect events per day per EVSE in mid-2013 for unknown reasons. While the DCFC in San Diego showed very high usage in early 2013, it rapidly declined by the end of the year.



Source: Blink Network

Figure 75 summarizes the total energy delivered by each DCFC in the region by month.

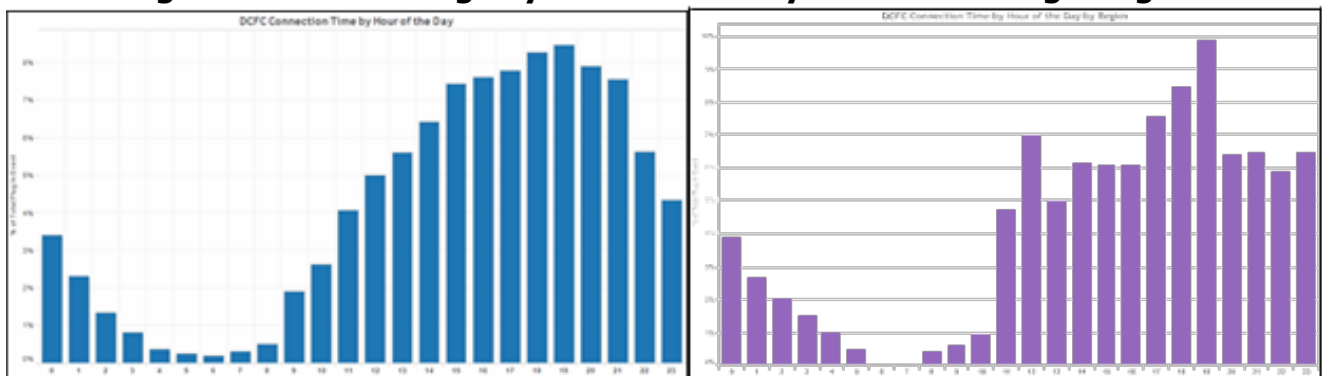
Figure 75: San Diego Region DCFC – Energy Delivered by Unit



Source: Blink Network

PEV drivers connect to DCFC at times displayed in Figure 76. National data is displayed on the left and San Diego region on the right.

Figure 76: DCFC Usage by Hour Nationally and in San Diego Region

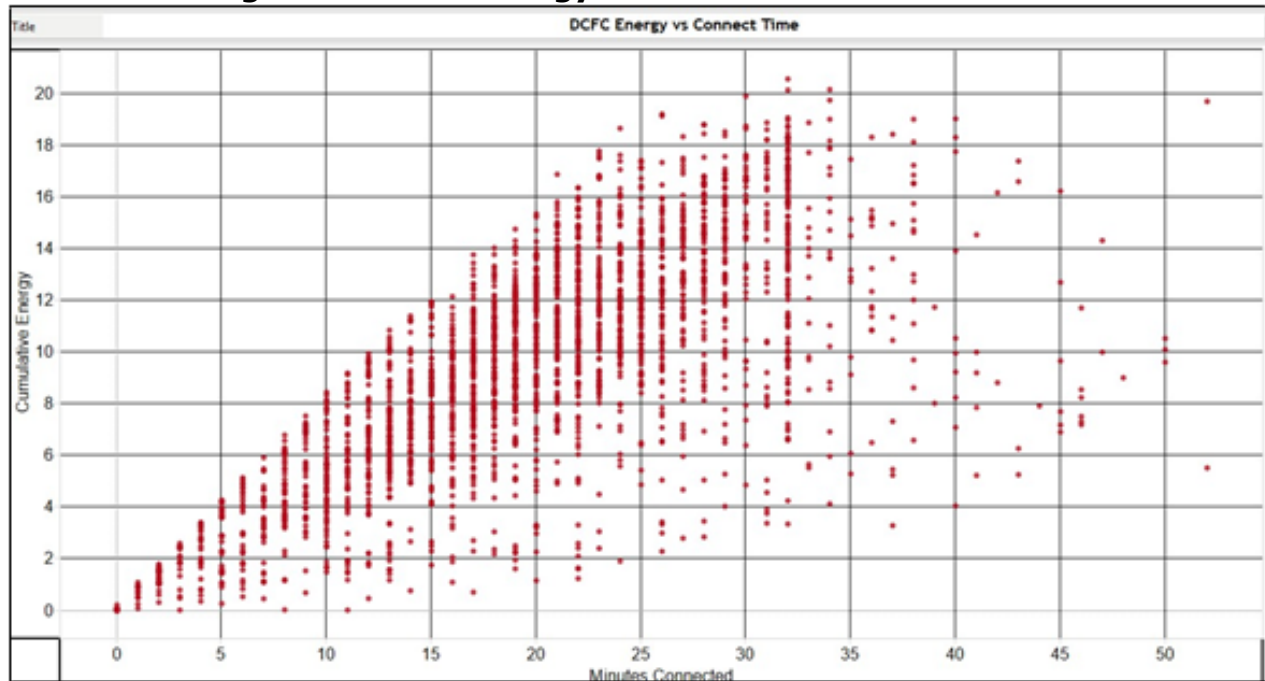


Source: Blink Network

While San Diego follows the national trend, there are slight variations likely because the sample size of number of DCFC is smaller, so each unit has a greater impact in the overall curve.

Figure 77 shows the energy delivered per charge event. The maximum energy delivered is approximately 20 kW.

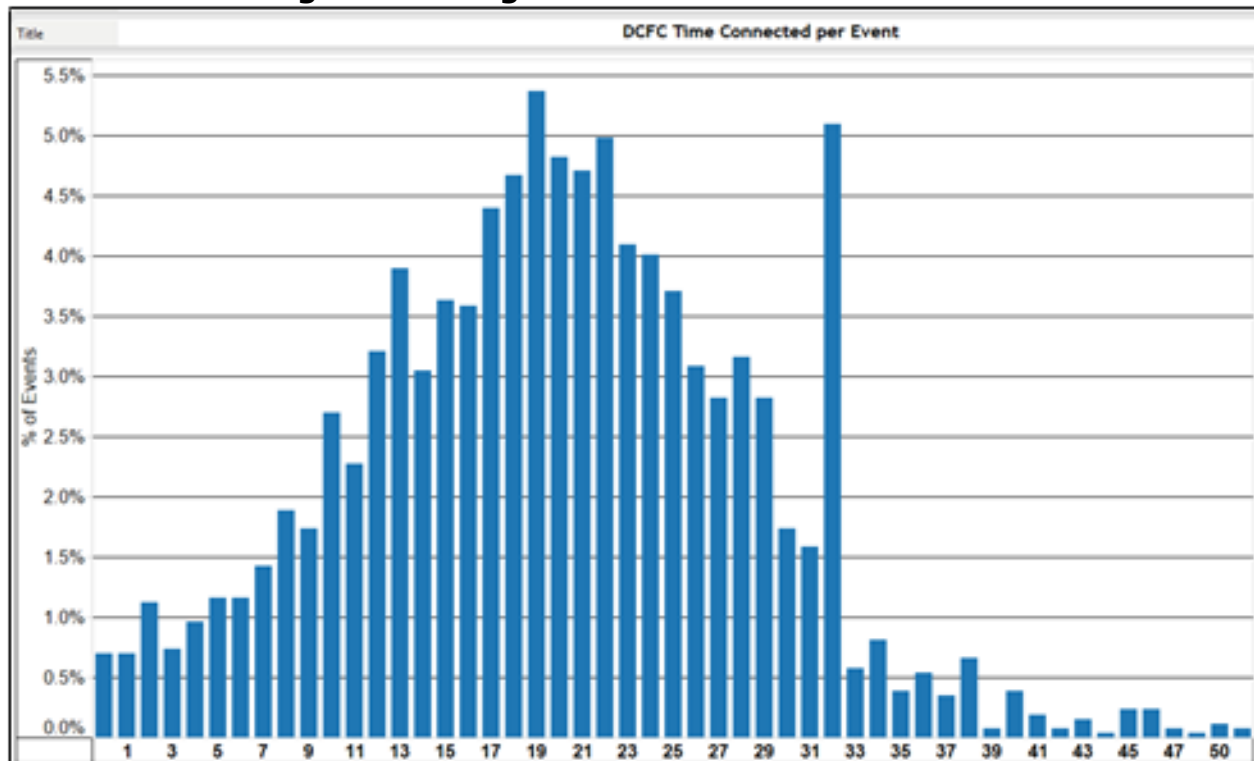
Figure 77: DCFC Energy Delivered vs Time Connected



Source: Blink Network

Vehicles connect to the DCFC for varying times as shown in Figure 78. The average for San Diego DCFC is 19.9 minutes. Because of the number of units analyzed and the unknown availability of the units, the significance of this charge duration for San Diego being 20 percent less than the EV Project average is uncertain.

Figure 78: Length of Time Connected to DCFC



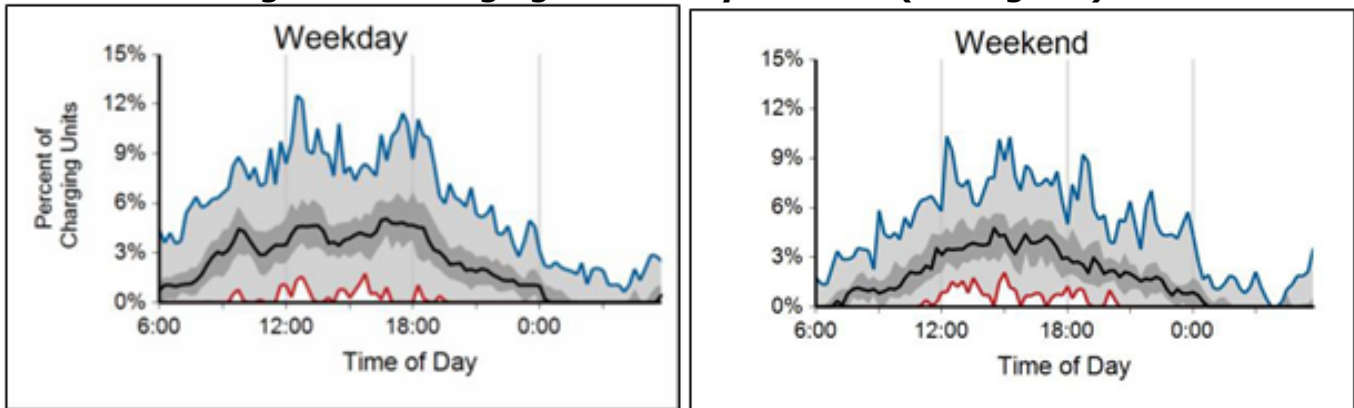
Source: Blink Network

Grid Impact of DCFC Charging

The use of DCFC has an impact on the electric grid. The Blink DCFC power rating is up to 60 kW, and routinely provides up to 50 kW for the Nissan Leaf.

Nationally, time-of-day plots display the impact of DCFC in Availability and Demand curves as described above. Figure 79 shows the charging availability of all DCFC in the project in the fourth quarter 2013. The rougher curves reflect the fewer numbers of DCFC than the smooth curves of the AC Level 2. Each connect has an impact.

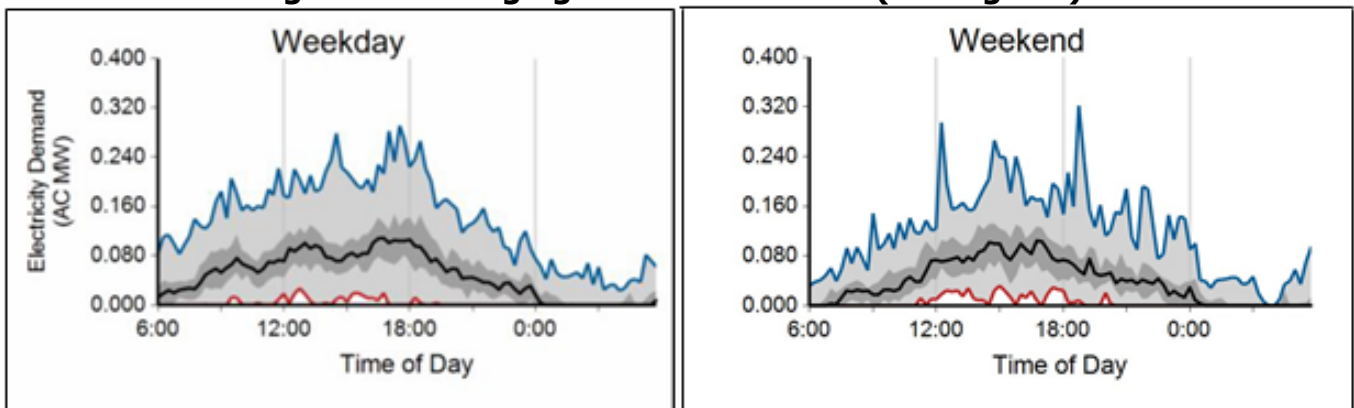
Figure 79: Charging Availability for DCFC (All Regions)



Source: Blink Network

Charging demand is the impact of DCFC on the grid. Figure 80 provides the national impact for all DCFC. Note that the scale for DCFC is megawatts and while fewer than AC Level 2, provide a significant impact to the grid.

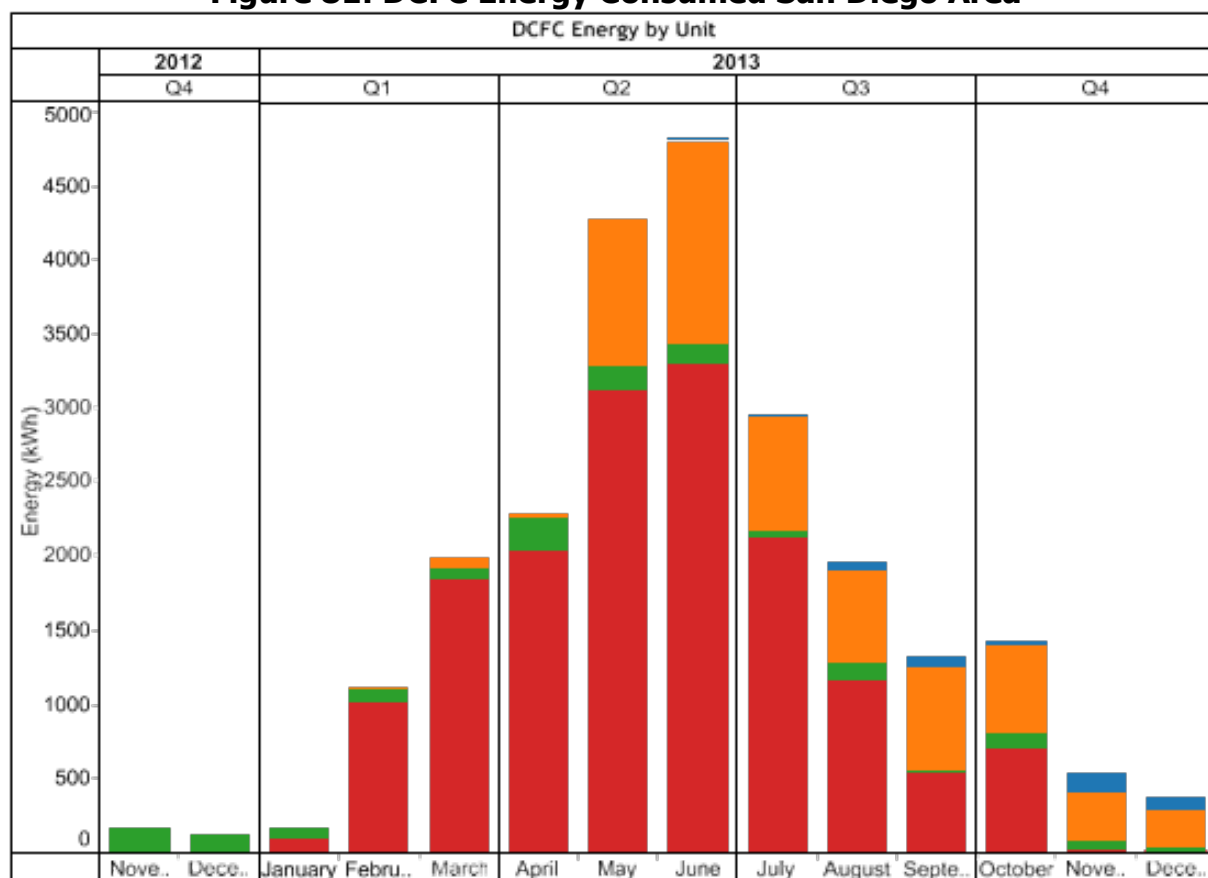
Figure 80: Charging Demand for DCFC (All Regions)



Source: Blink Network

For the DCFC in the San Diego Region, Figure 81 shows the energy demand by month.

Figure 81: DCFC Energy Consumed San Diego Area



Source: Blink Network

Vehicle Use Observations

The EV Project collected a significant amount of vehicle use data during the three years. Table 2 shows some of the statistics for the national and San Diego areas in the fourth quarter 2013.

Table 8: Leaf and Volt Usage

	EV Project Overall		San Diego	
Vehicle	Leaf	Volt	Leaf	Volt
Number of Vehicles	3,499	1,611	401	216
Distance Driven (Miles)	5,258,445	4,673,200	619,077	611,913
Average Daily Travel (Miles)	26.7	39.8	26.7	39.6
Average Number of Charge Events/Day	1.1	1.5	1.1	1.3
Frequency of Charging at Home	75%	79%	77%	79%

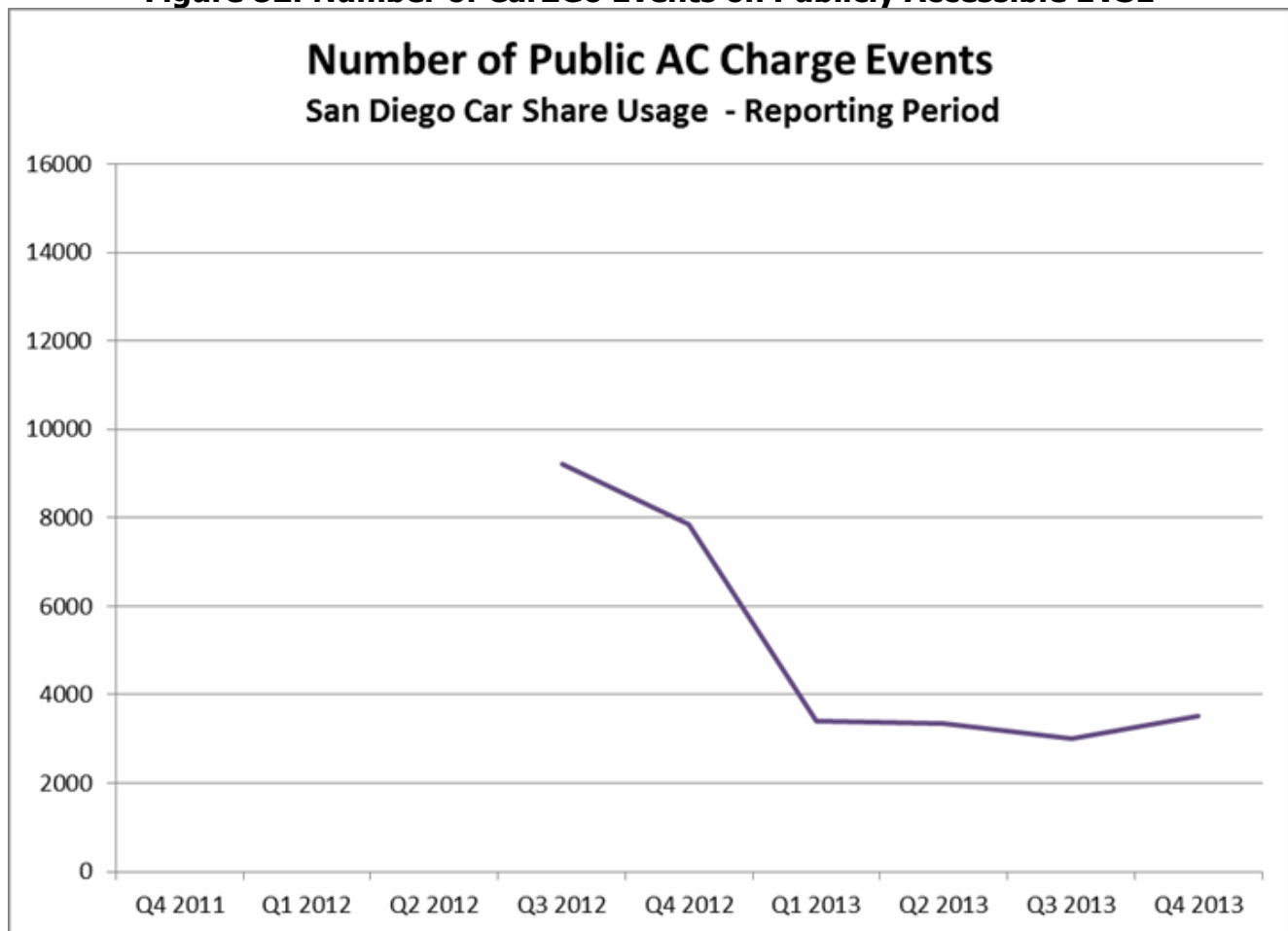
Source: Blink Network

In San Diego, the average daily distance driven by the Leaf owner declined from 30.7 miles in the fourth quarter 2011 to 26.7 in the fourth quarter 2013. The average daily distance driven by the Volt driver remains relatively constant from the fourth quarter 2011. The Volt drivers in San Diego were right about on average as 70.4 percent of their travel was in EV mode (battery power) while the national average is 71.1 percent. Chapter 5 provides more information on vehicle use patterns.

Car Sharing Information and Observations on Car2Go

In the fourth quarter 2013, there were 416 Smart-For-Two EVs enrolled in the EV Project from Car2Go's vehicle sharing program; 386 of which were in San Diego. The usage of vehicles in this car sharing program require public infrastructure along with EVSE installed in their fleet location. The project tries to identify the use of publicly available EVSE by vehicle type and can do so if the vehicle participates in the project. Vehicles outside the project charge at these EVSE and the charge data recorded but the recipient of the charge is unknown. In the fourth quarter 2013, charging by Car2Go accounted for 22 percent of the charge events and 30 percent of the energy consumed by the publicly available EVSE while 67 percent of the events and energy were by unknown vehicles. Figure 83 shows the number of charge events on publicly accessible EVSE since the third quarter 2012.

Figure 82: Number of Car2Go Events on Publicly Accessible EVSE

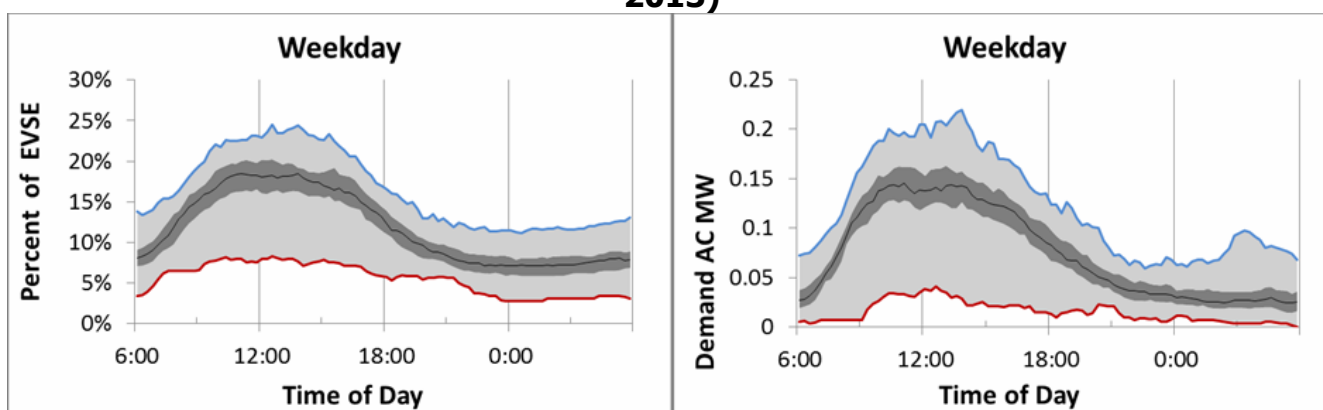


Source: Blink Network

As the number of publicly accessible EVSE and the number of participating vehicles in the San Diego area increased, the percentage of events by Car2Go on these EVSE has declined from 60 percent in the third quarter 2012 to 22 percent in the fourth quarter 2013. As Car2Go refined their model, they added dedicated charging locations, which were not available to the public. This likely led to the reduction in use of publicly available units noted above. Nevertheless, the interest lies in determining whether a significant impact exists on the use and electrical demand from these car sharing vehicles.

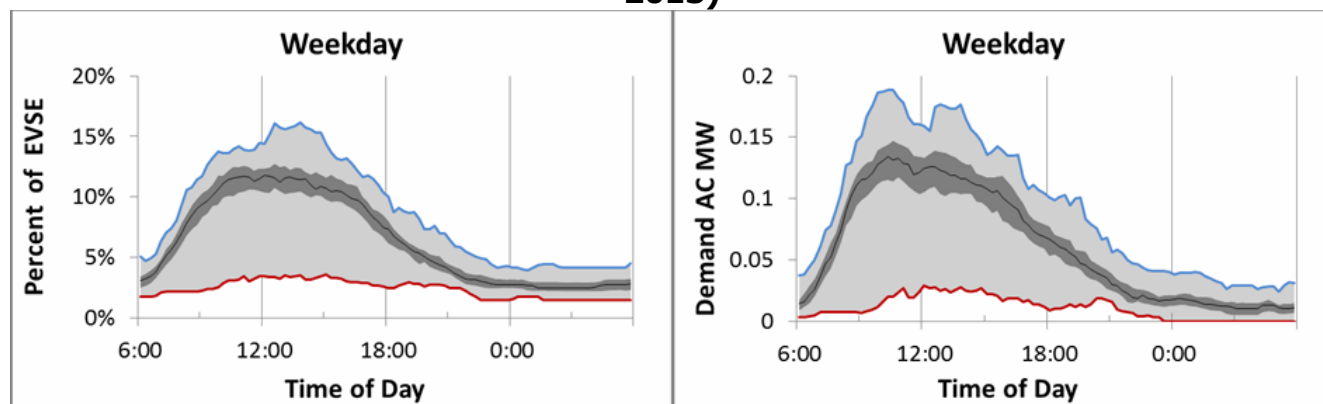
Figure 83 shows the weekday Charging Availability and Charging Demand in San Diego and Orange Counties in the fourth quarter 2013. Figure 84 shows the same time period subtracting out the known Car2Go charges. Figure 85 shows a comparison of the median values for each of the curves.

Figure 83: Charging Availability and Charging Demand with Car2Go San Diego (Q4 2013)



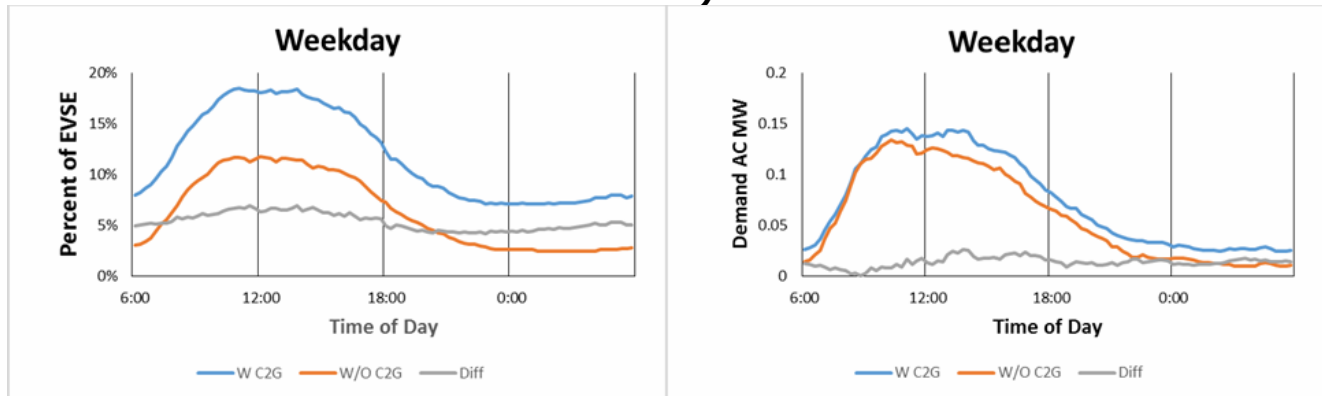
Source: Blink Network

Figure 84: Charging Availability and Charging Demand San Diego w/o Car2Go (Q4 2013)



Source: Blink Network

Figure 85: Charging Availability and Charging Demand Median Comparison (Q4 2013)



Source: Blink Network

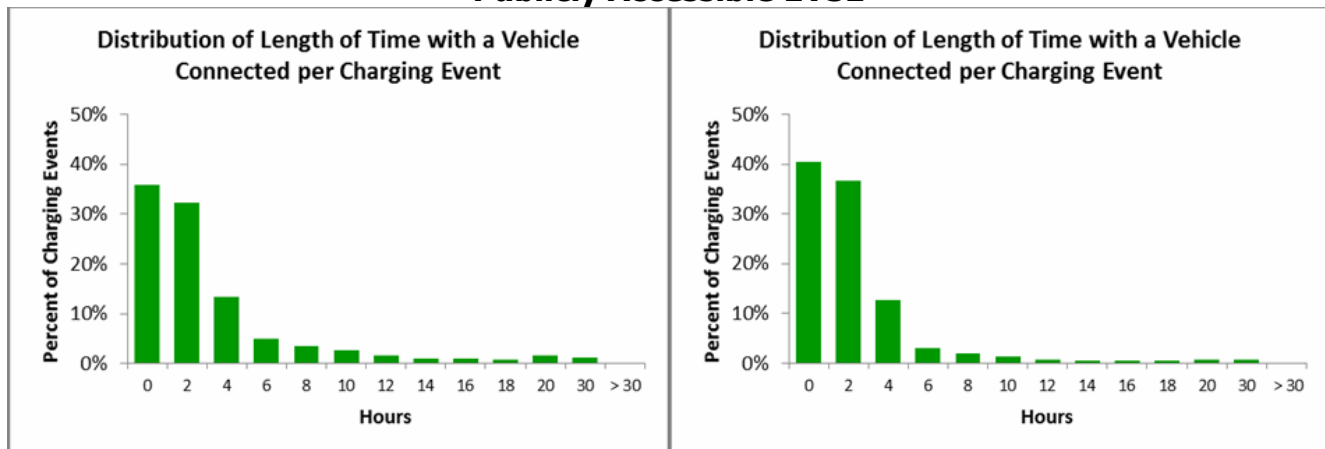
The significant difference occurs in the charging availability. In a fairly consistent manner, the Car2Go vehicles add approximately 5 percent to the time the publicly accessible EVSE are connected to a vehicle throughout the entire day. The actual demand on the grid difference is very minor.

The length of time that a vehicle remains connected is also of interest. Figure 86 shows the distribution of time that a vehicle is connected per charge event with and without the influence of Car2Go.

The length of time that a vehicle remains connected increase as Car2Go is considered. Thus, Car2Go vehicles tend to remain connected longer than PEV owned vehicles remain.

As more PEVs are added to the San Diego and Orange County areas, the relative impact of car sharing on the grid will continue to decrease but they will still add the demand noted above. They will also generally reduce the availability of publicly accessible EVSE to private PEV owners.

Figure 86: Distribution of Vehicle Connected Time (with and without Ca2Go) Publicly Accessible EVSE



Source: Blink Network

Chapter 5: Data Analysis

Chapter 4 presented the results in the planning and deployment phases of the EV Project. The results present specific data points from which observations are drawn. Chapter 5 presents more observations on the data collected and how this may impact the current thinking and planning for further study and deployment. Included here are observations on topics of specific interest to the CEC and show how the San Diego area compares to balance of EV Project areas.

Factors with the Potential to Influence Vehicle Design and Use Vehicle Use Patterns

A UC Davis study: "*Studying the PEV Market in California: Comparing the PEV, PHEV and Hybrid Markets*"¹³, conducted in 2013, examined the differences in driver habits between BEVs and PHEVs in California. They specifically examined average daily mileage based on odometer readings and commute trip distance. More than 80 percent of BEVs are identified as commute vehicles but only 58 percent commute daily with their BEV. Not surprisingly, PHEVs are used more often for work commutes, and for longer distances. Regional differences exist as well between vehicle types. A larger number of PHEV owners reside in the Los Angeles area likely due to the longer distances traveled between destinations compared to the San Diego area. The study showed that in the Bay Area, EV owners living in the inner ring of the metropolitan area had a higher ratio of BEVs while the owners living further away had a higher ration of PHEVs. The survey was self-reporting, but owner appeared to accurately identify their average daily driving distances. In San Diego, the survey reports a daily Volt travel distance of 36.5 miles compared to EV Project's data showing a travel distance of 39.6 miles. The survey reports a daily Leaf travel distance of 26.8 miles which compares to the 26.7 travel miles from EV Project data.

Vehicle use patterns include trip distances and daily travel as well as distance driven between charge events. A "trip" is defined as the distance from a "key-on" event (or vehicle start) and the subsequent "key-off" event (or vehicle stop). More than one trip may be included in the daily travel distances. Daily distances also refer to the average of days when the vehicle was driven. It does not average the distances for days the vehicle was idle.

Table 9 compares vehicle use patterns between the Leaf and the Volt for all EV Project regions in the fourth quarter 2013 while table 10 compares that of the San Diego region. At the end of the quarter, there were 3,499 Leaf vehicles and 1,611 Volt vehicles still reporting data.

¹³ [Studying the PEV Market in California: Comparing the PEV, PHEV and Hybrid Market](https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2099)
https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2099 [Accessed April 10, 2014]

Table 9: Leaf and Volt Vehicle National Use (Q4, 2013)

Vehicle	Number of Trips	Avg Trip Distance (Mi)	Avg Distance traveled per day when driven (Mi)	Avg Distance between Charge Events (Mi)	Avg number of Charge Events per Day when Driven
Leaf	781,062	6.7	26.7	23.9	1.1
Volt	559,680	8.2	39.8	27.2	1.5

Source: Blink Network

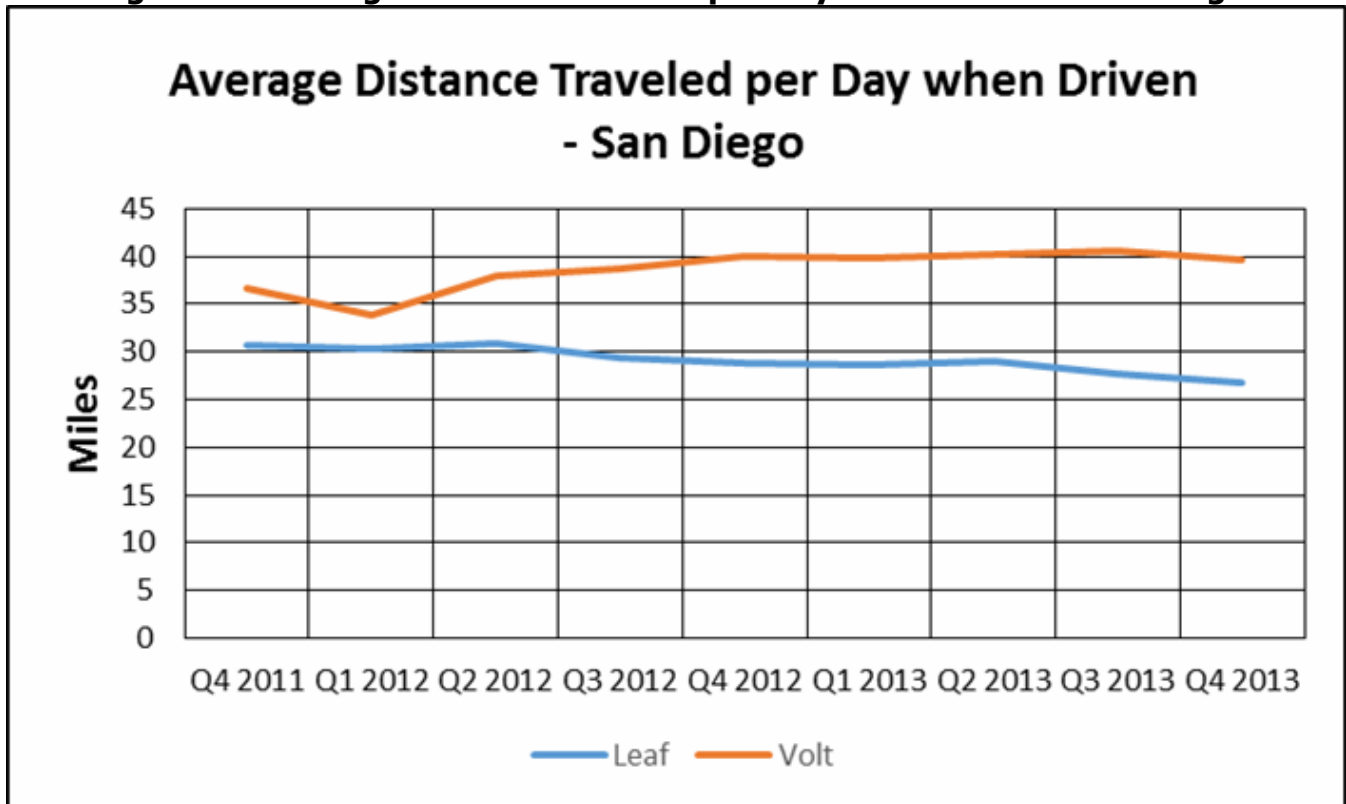
Table 10: Leaf and Volt Vehicle - Use San Diego (Q4, 2013)

Vehicle	Number of Trips	Avg Trip Distance (Miles)	Avg Distance traveled per day when driven (Mi)	Avg Distance between Charge Events (Mi)	Avg number of Charge Events per Day when Driven
Leaf	94,253	6.6	26.7	24.6	1.1
Volt	71,886	8.2	39.6	30.1	1.3

Source: Blink Network

The San Diego region closely following the national trend. The Volt driver typically takes slightly longer trips, travels 50 percent farther each day when driven, drives 14 percent farther between charge events and recharges 36 percent more during the day than the Leaf driver. Figure 87 compares the average distance traveled per day when driven.

Figure 87: Average Distance Traveled per Day when Driven – San Diego



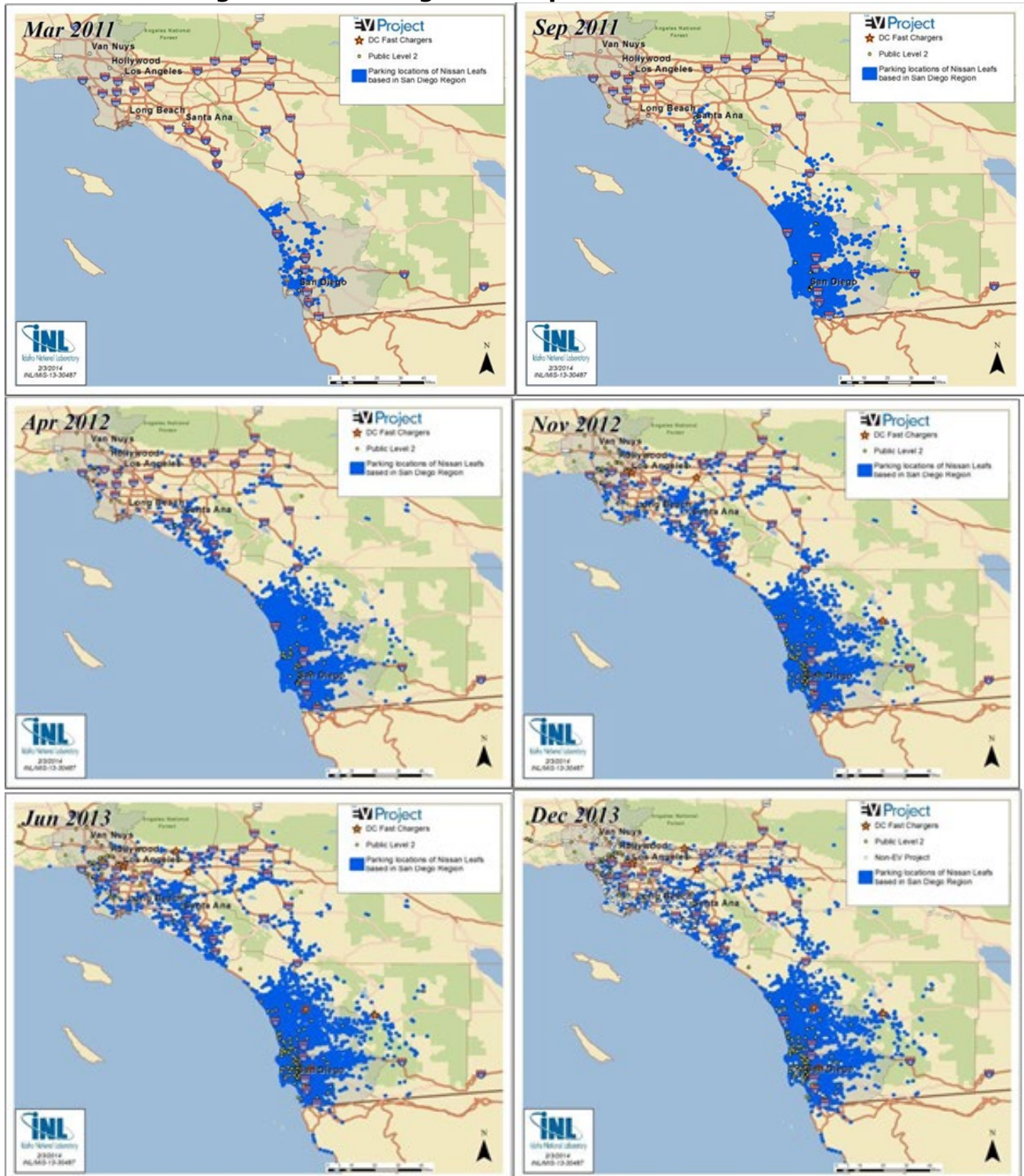
Source: Blink Network

The average distance traveled per day by the Leaf driver has declined from the initial days of the EV Project while that of the Volt driver has increased but is showing a slight decline in the last half of 2013. It may be that the adopters of the Leaf later in the EV Project had specific purposes in mind when selecting the Leaf, such as a commuting vehicle, or later adopters were simply less aggressive in their use. More information is provided on travel distances later in Chapter 5.

The EV Project gathered data on vehicle trips including GPS position at key-off events, which one would assume are travel end points. A time study of these trip end points develops a story of how the infrastructure growth as well as a driver's familiarity with their vehicle results in greater mobility. The BEV Nissan Leaf is of greatest interest because of its reliance solely on its battery for motive power. To expand the region of travel, public infrastructure is required.

Figure 88 identifies the growth in travel of Nissan Leafs home based in San Diego over the EV Project study period. All these trip end points are from Leafs whose residences are within the San Diego area. The expansion of infrastructure not only in San Diego but also in the Los Angeles region greatly increased the actual area of travel.

Figure 88: San Diego Leaf Trip End Points over Time



Source: Blink Network

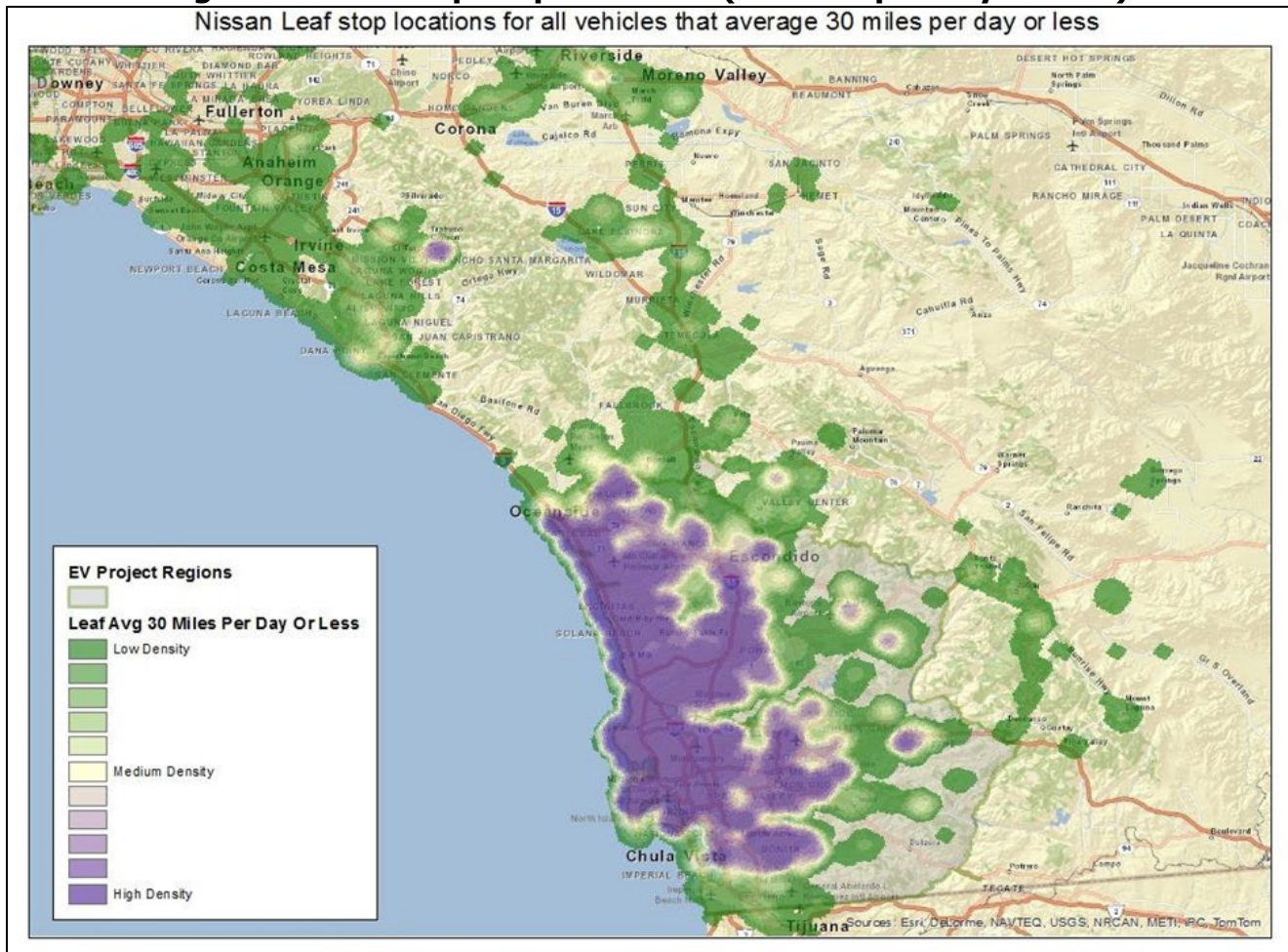
Vehicle End of Trip Locations

The density of the end of trip points is also of interest because it shows locations to which PEVs travel and park. Eliminating the home locations, the resulting plots show locations which may be excellent locations for the placement of away-from-home charging.

The trip end point shown in the following figures are for only those participants residing in the San Diego area. The first three figures are Leaf stop locations and the next three are Volt stop locations.

The plots are sorted by the average daily mileage of the participating vehicle. For example, Figure 89 shows stop locations for Leaf vehicles that average 30 miles or less per day. These vehicles may travel more than 30 miles in a day but its data for those days are still included in Figure 89. For comparison purposes, the plots include the shorter trips (i.e. 30 miles or less per day), trips that are near the farthest range of the battery only motive power (i.e. 50 miles for Leaf and 35 miles for Volt) and for all trips.

Figure 89: Leaf Trip Stop Locations (30 Miles per Day or Less)



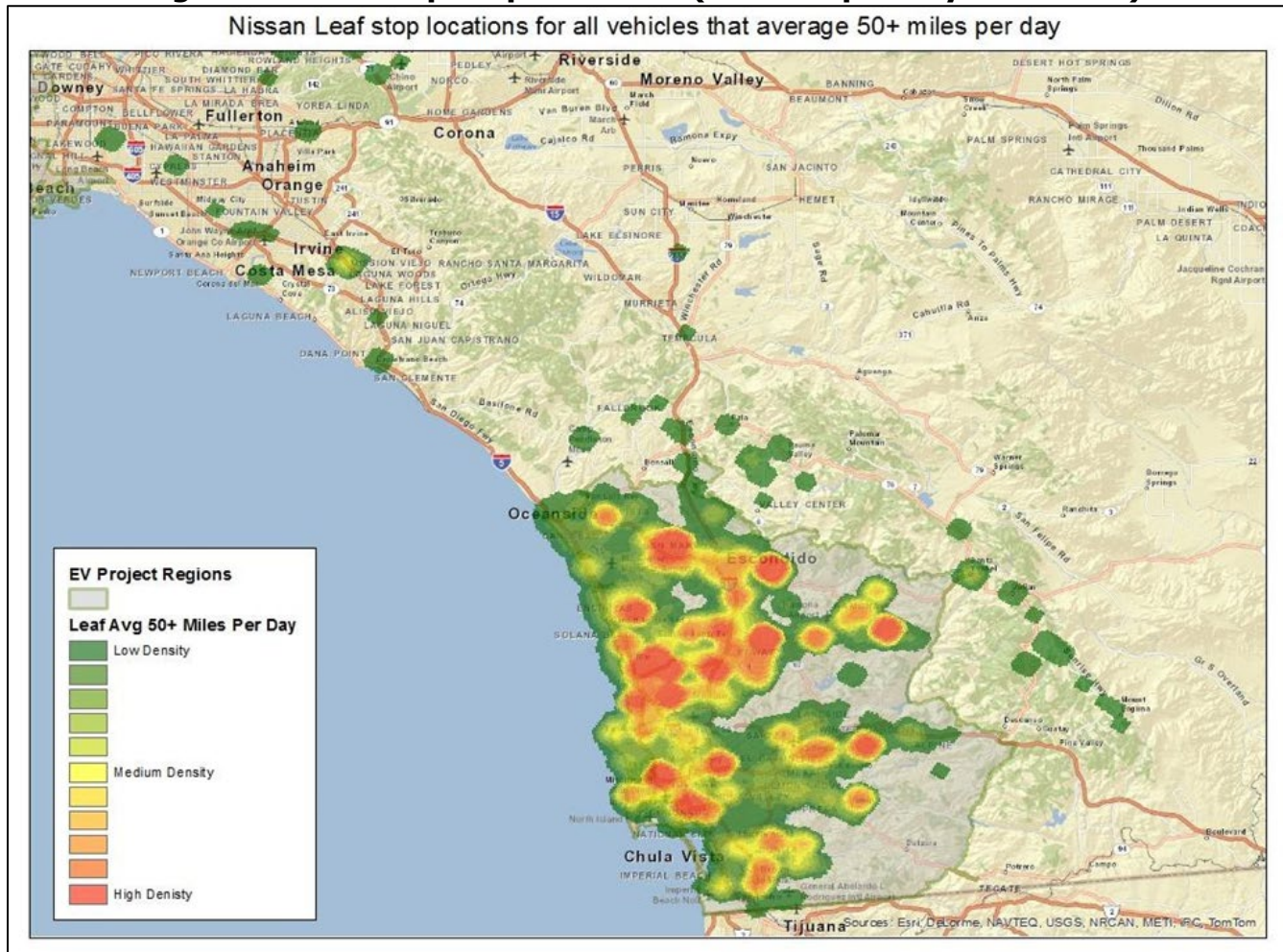
Source Blink Network

Leaf vehicles that average 30 miles or less per day typically do not require charging away from home. However, none of the locations above is a residential location so the drivers are utilizing public or workplace EVSE. These drivers who typically remain close to home have taken extended trips away from the San Diego area. Utilization of public infrastructure would be required to complete these trips.

Operators of Leaf vehicles that travel more than 50 miles/day may utilize publicly available EVSE located in the highest density locations. They may need the opportunity charging capability to return to their residence. Locations farther remote from the metropolitan areas

may also be good locations for public EVSE. A vehicle traveling more than 50 miles/day may stop at several locations on a single outing away from home. Figure 90 shows the Leaf trip end points for these drivers.

Figure 90: Leaf Trip Stop Locations (50 Miles per Day or Greater)

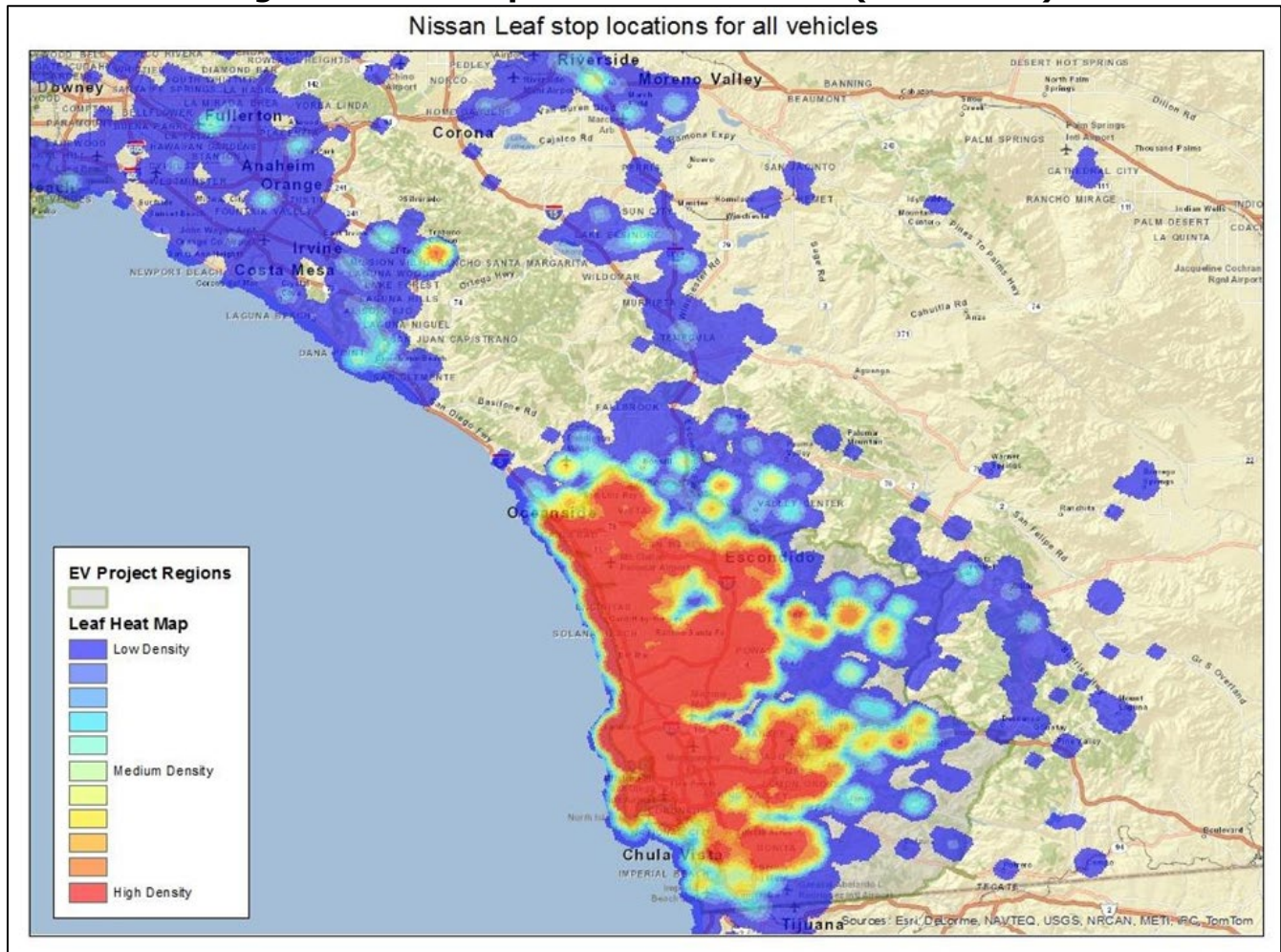


Source: Blink Network

It appears that the Leaf drivers who average 50 or more miles per day do not venture as far away from their San Diego home as those who average 30 miles per day or less. However, the sample size of those traveling more than 50 miles per day is much smaller than those traveling 30 or fewer miles per day.

Figure 91 shows the trip end points for all Leaf drivers including those who average between 30 and 50 miles per day.

Figure 91: Leaf Trip End-Point Locations (All Vehicles)

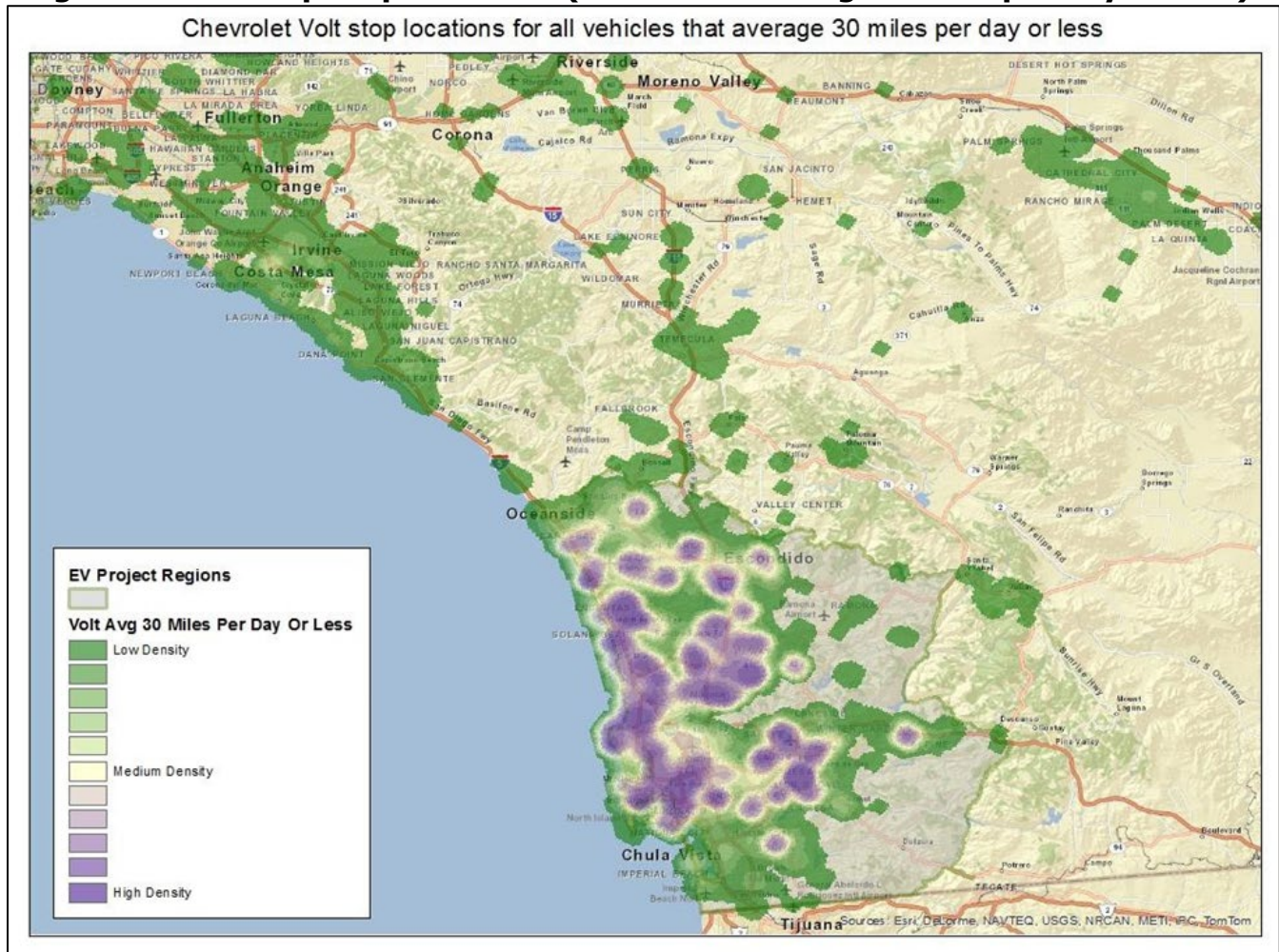


Source: Blink Network

The high-density locations may be the best locations for publicly accessible EVSE. Although many of the stop locations could be workplace, certainly the trips beyond the greater San Diego area require the use of public charging. With the advertised range of the Leaf about 70 miles, any endpoint more than 35 miles from the EV Project boundary could be a candidate for public charging. It is also evident that the trips into the Los Angeles area or Moreno Valley or Palm Springs would not be possible without the expanding infrastructure in those areas.

Volt drivers are not limited by range except by their own “gas anxiety”, that is the observed desire of Volt drivers to maximize the use of the battery for motive power and avoid gasoline use.

Figure 92: Volt Trip Stop Locations (Vehicles Traveling 30 Miles per Day or Less)

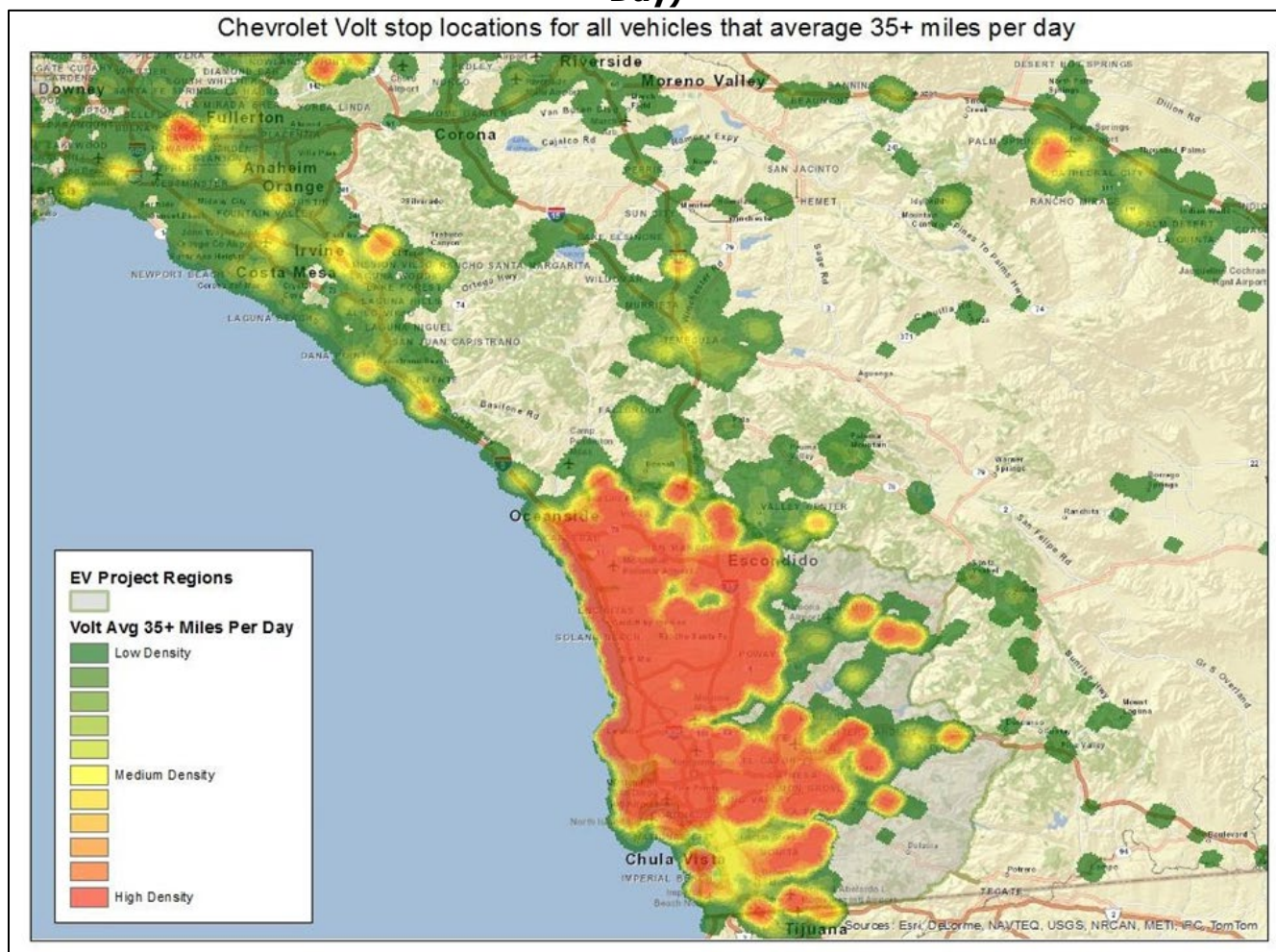


Source: Blink Network

Although averaging 30 miles or less per day, some drivers do take extended trips away from home as identified for the Leaf driver above. Many of the locations coincide although several Volt locations are more remote and more distant.

Figure 93 shows the trip end points for Volt drivers who average more than 35 miles per day. This would typically deplete the battery only portion of the trip. There are a significant number of trips beyond the San Diego home.

Figure 93: Volt Trip Stop Locations (Vehicles that Travel More Than 35 Miles per Day)



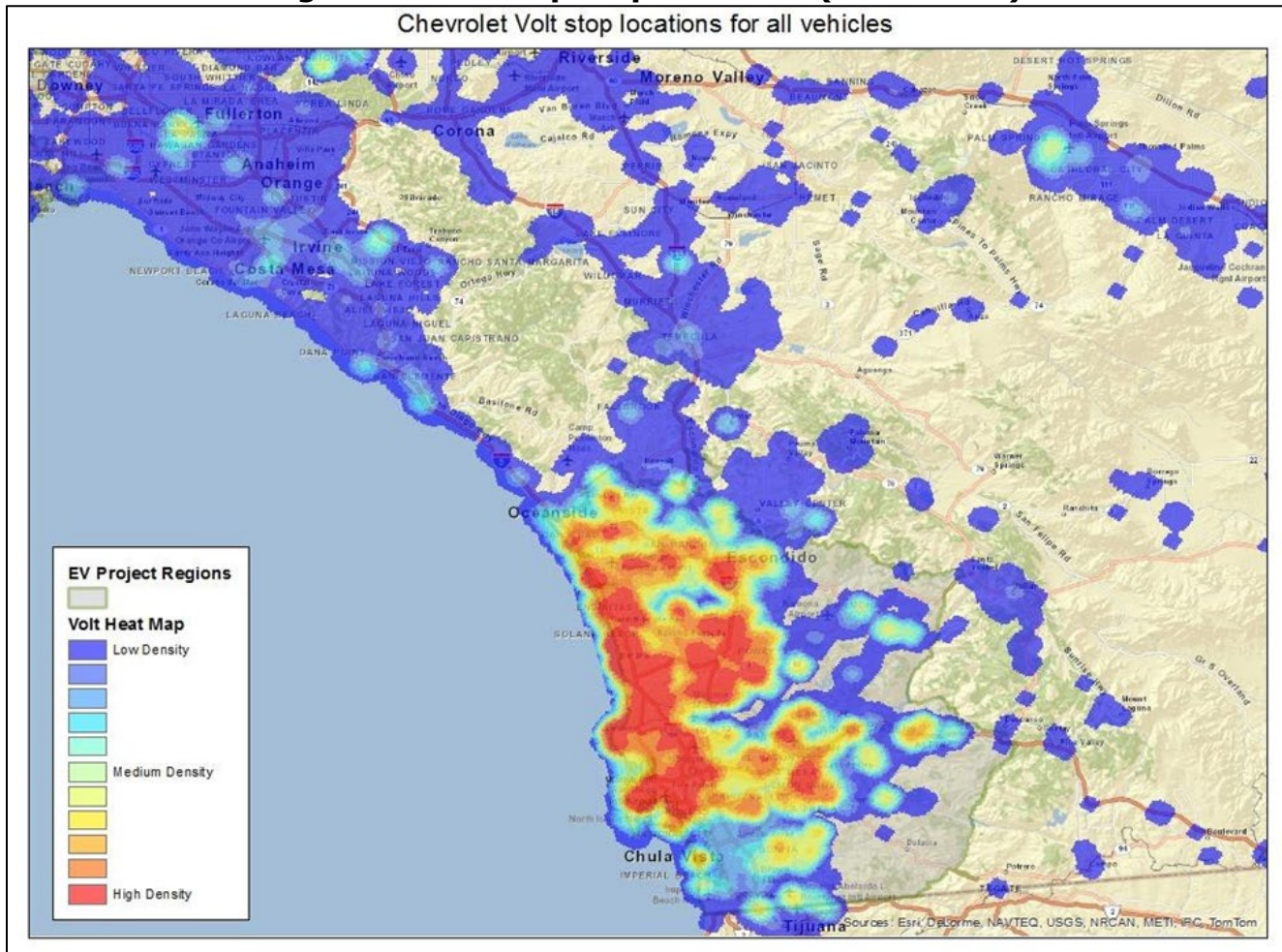
Source: Blink Network

Volt drivers traveling more than 35 miles per day may be interested in publicly accessible EVSE for opportunity charging in these high-density spots to travel more on battery power. Indeed, these drivers may utilize public charging located in other regions.

Figure 94 shows the trip end points for all Volt drivers.

Figure 94: Volt Trip Stop Locations (All Vehicles)

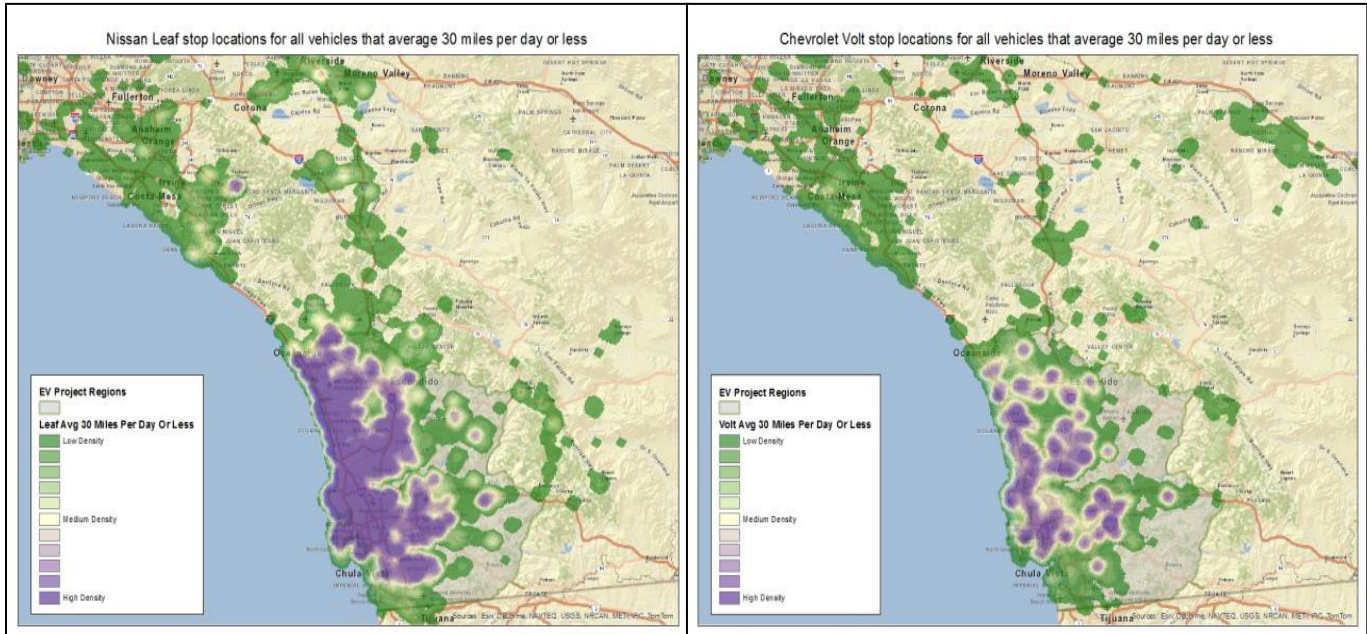
Chevrolet Volt stop locations for all vehicles



Source: Blink Network

To gain additional insight, the trip end points for the Leaf driver and the Volt driver who average 30 or less miles per day are shown side-by-side in Figure 95. With the exception of the Palm Springs area, both vehicles are accessing the same territory. The range of the Leaf (BEV) does not appear to be a hindrance relative to the territory traveled when compared to the Volt (EREV).

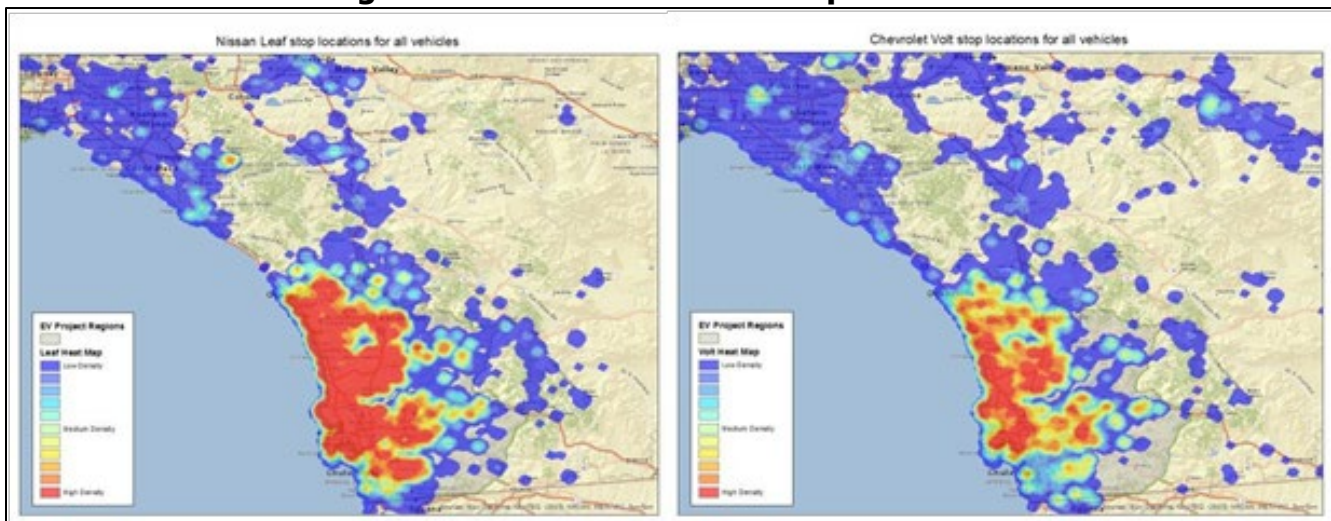
Figure 95: Leaf and Volt Stop Locations for Vehicles that Average 30 Miles per Day or Less



Source: Blink Network

Figure 96 shows the trip end points for all Leafs and Volts.

Figure 96: Leaf and Volt All Stop Locations



Source: Blink Network

As before, the territory covered by both vehicles is very similar. Again, the Volt driver accesses the Palm Springs area more, but it would appear that there is no real limitation on the Leaf driver because of range.

Charging Frequencies and Profiles

Southern California Edison (SCE), whose customers support nearly 10 percent of the national EV sales, published "*Charged UP: Southern California Edison's Key Learning about Electric*

Vehicles, Customers and Grid Reliability"¹⁴. SCE reports 65 percent of customers who own PEVs drive a PHEV and about 35 percent drive a BEV. Fifty percent of PHEV drivers charge at AC Level 1EVSE, which SCE identifies as a reduced grid impact. SCE reports less than 1 percent of transformer upgrades are directly attributable to PEVs and in all cases, the grid needed reinforcement regardless of PEVs.

Most PEV drivers charge once per day at night at home. Recharging is typically using AC Level 1 EVSE. SCE also noted that less than 40 percent of those with access to workplace charging actually take advantage of it. SCE notes that a driver using the charge end time for programming is valuable in leveling the load impact. A surveyed sample of early adopters indicated that any "range anxiety" that they felt had been eliminated after driving their new BEV over time.

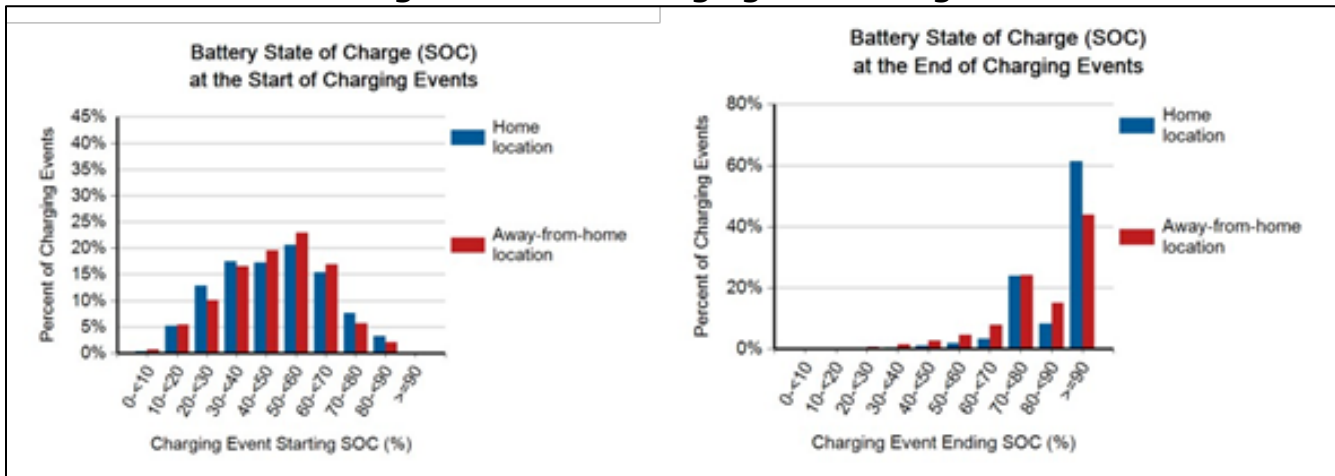
SCE notes that there is a growing adoption of BEVs with higher charging capabilities (i.e. 3.3 kW replaced by 6.6 kW or higher) and that might have implications for grid impact requiring further study.

Vehicle Charging

Leaf and Volt drivers charge their vehicles differently because of unique vehicle characteristics. Figure 98 shows the Leaf battery state of charge at the start and end of the charging events based upon home and away-from-home locations. For both locations, the battery states of charge at the beginning of charges are very similar. It is not surprising that the beginning state of charge is not in the lowest bin of less than 10 percent state of charge since the Leaf driver would not generally operate near the lower limit of battery availability. It is also not surprising that once connected, the Leaf driver typically completes the charge to achieve a high state of charge. Once connected and charging, the Leaf driver would typically interrupt the charge only to take another trip. Since most of the Leaf charging in San Diego is at night at reduced time-of-use rates, this charging occurs in the early morning hours. The fact that the end of charge at away-from-home locations is typically in the upper state of charge percentages reflects the low overall daily mileage of the Leaf driver so that the battery is relatively high at the beginning of charge as also shown in Figure 97.

¹⁴ [Charged Up: Southern California Edison's Key Learning about Electric Vehicles, Customers and Grid Reliability](http://newsroom.edison.com/internal_redirect/cms.ipressroom.com.s3.amazonaws.com/166/files/20136/SCE-EVWhitePaper2013.pdf)
http://newsroom.edison.com/internal_redirect/cms.ipressroom.com.s3.amazonaws.com/166/files/20136/SCE-EVWhitePaper2013.pdf [Accessed April 10, 2014]

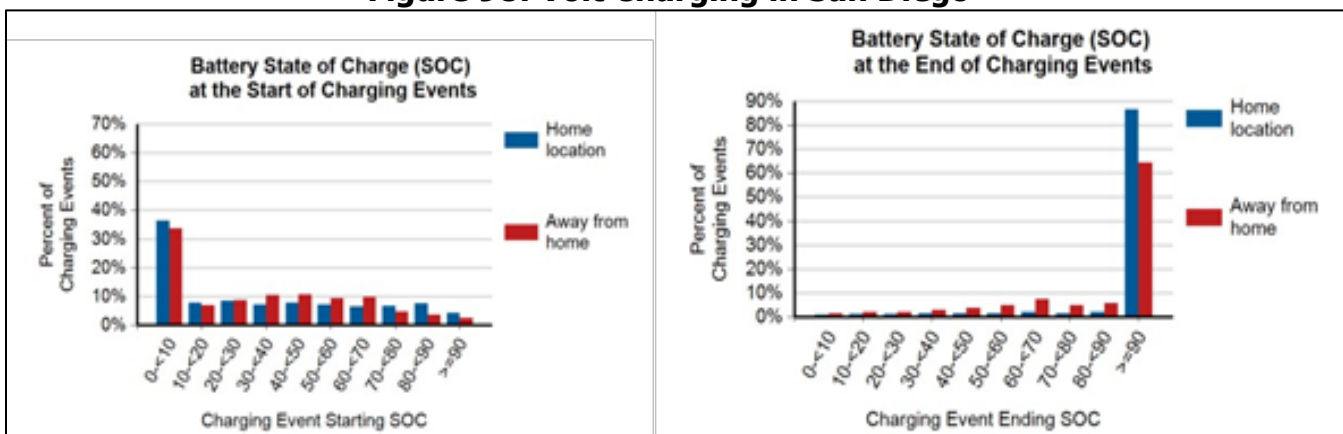
Figure 97: Leaf Charging in San Diego



Source: Blink Network

The Volt driver in San Diego follows a different charge routine. Figure 98 shows the same figures for the Volt driver in the fourth quarter 2013. Because the Volt has a lower battery capacity and the Volt driver travels farther each day than the Leaf driver, it is much more likely that the Volt will be at a low state of charge when connecting to an EVSE. It is likely that the Volt will be in Extended Range Mode (or charge sustaining mode) when first connected. Like the Leaf, the Volt will likely be at a high state of charge at the end of the charge. Because the battery capacity is less than that of the Leaf, the recharge time is much shorter so the time to completely charge the battery is less. Like the Leaf, the Volt driver may disconnect before the battery is fully charged and this is more likely when the vehicle is away from home.

Figure 98: Volt Charging in San Diego



Source: Blink Network

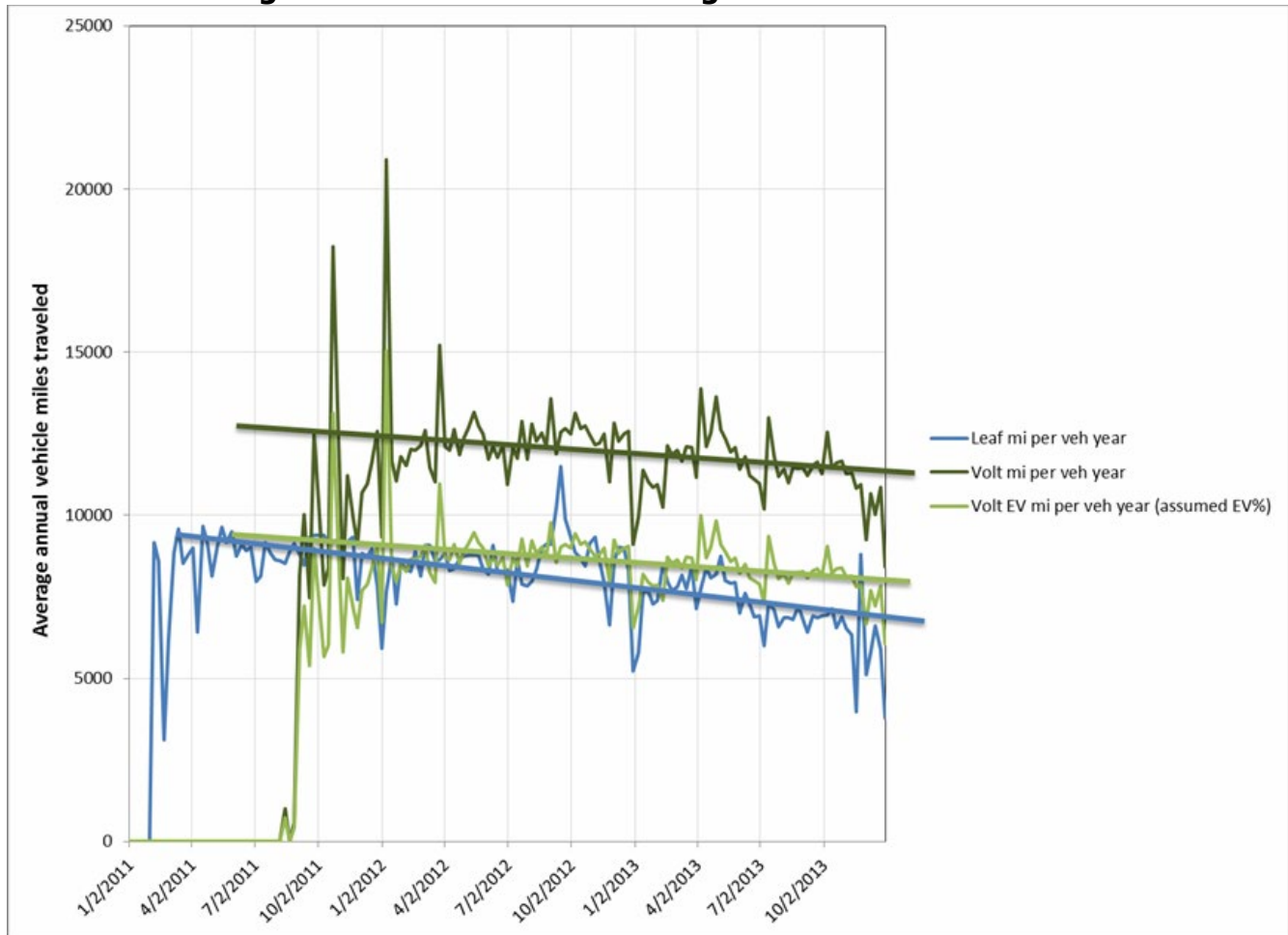
Electric Fuel Use

The adoption of PEVs in the EV Project regions shifts the personal transportation fuel from gasoline and diesel to electric. For the Nissan Leaf driver, all travel is powered from the on-board battery so all miles are on electric fuel. The Volt provides the gasoline engine for travel beyond the approximate 40 miles provided by the battery. The Volt then has a combination of EV Mode for electric and Extended Range Mode for gasoline. The EV Mode is often called

“charge depleting” mode and Extended Range is “charge sustaining” mode. Both vehicles provide a lower limit to the ultimate depletion of battery charge.

The Volt entered the EV Project later than the Leaf as shown in Figure 99. This figure shows the average annual vehicle miles for both vehicles. The Volt data shows both total miles and miles in EV Mode.

Figure 99: Leaf and Volt Average Annual Vehicle Miles



Source: Blink Network

It is noteworthy that although Volt drivers consistently travel longer distances daily than Leaf drivers, both displayed the same annual mileage in EV Mode early in the project. The Volt driver displays a slight reduction over the project in annual miles (at the same rate as Volt EV Mode) but the decline is more distinct for the Leaf.

Leaf and Car2Go Electric Fuel Use

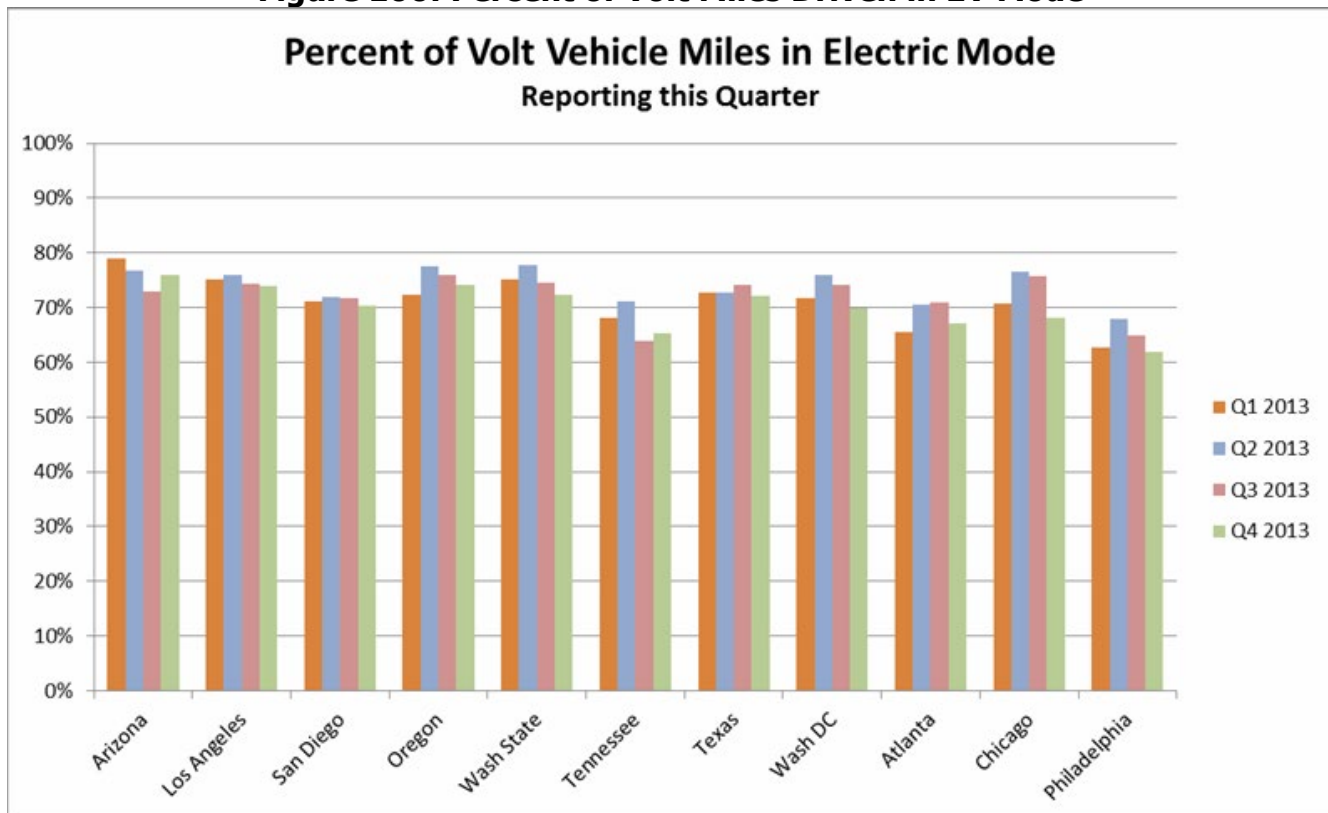
As all travel by the Leaf is on electric motive power, the total miles recorded in the EV Project of 89,175,939 miles driven are electric. Of that, San Diego travel accounted for approximately 12,500,000 miles. In addition, the 2,906,168 miles by SmartForTwo are all electric drive. In San Diego, the SmartForTwo travel accounted for approximately 2,700,000 miles.

EV Mode/Extended Range Mode for Volt

The amount of travel conducted in EV Mode can be controlled by the driver. The flexibility of driving a vehicle not limited by range allows the driver to use the vehicle for any purpose or trip. However, the desire of Volt drivers to utilize the EV Mode as much as possible and avoid the use of gasoline (i.e. gas anxiety) is evident in the EV Project.

In the first quarter 2013, OnStar separated miles driven into EV and Extended Range Modes to allow greater analysis. Figure 100 shows the percentage of miles driven in Electric Mode since first reporting for all EV Project regions. In the fourth quarter 2013, San Diego Volt drivers traveled 74.2 percent of miles in EV Mode compared to 73.4 percent nationally.

Figure 100: Percent of Volt Miles Driven in EV Mode



Source: Blink Network

During the fourth quarter 2013, 242 Volts in the San Diego region traveled 701,806 miles total. This is an average of 11,600 miles annually per vehicle which is just slightly above the national average shown in Figure 100 above.

At the same time, these 242 Volts traveled 503,403 miles in EV Mode. This is an average of 2,080 miles per Volt for an annual mileage of 8,320 miles each in EV Mode. Again, this is slightly above the national average shown in Figure 99. While this has varied since the beginning of the project, the miles in EV Mode have remained approximately 72 percent of the total miles recorded for the Volt.

The total miles driven by the Volt in the EV Project of 31,898,820 miles implies that approximately 22,960,000 miles are on battery power. Of that, approximately 3,088,000 were driven in EV Mode in the San Diego region.

The power consumed from the electric grid to travel these miles varies by model. The Leaf consumes 340 Wh/mile, the Volt consumes 360 Wh/mile and the SmartForTwo consumes 390 Wh/mile. Table 5 shows the energy consumed by these vehicles in the EV Project.

Table 11: Energy Consumed by EV Project Vehicles

Vehicle	Energy Consumed Nationally in EV Project (kWh)	Energy Consumed in San Diego in EV Project (kWh)	Average Annual Mileage	Average Annual Energy Consumed per Vehicle (kWh)
Leaf	30,320,000	4,250,000	6,500	2,210
Volt	8,265,000	1,112,000	7,750	2,790
SmartForTwo	1,133,000	1,051,000	3,500	1,365

Source: Blink Network

San Diego drivers travel 68 million miles per day with an average of 5.8 miles per trip on San Diego roads.¹⁵ In the fourth quarter 2013, Volt drivers in San Diego averaged 8.2 miles per trip and Leaf drivers averaged 6.6 miles per trip. The average daily travel by PEVs in the EV Project in the fourth quarter 2014 was approximately 24,000 miles per day. While the PEV drivers average slightly greater distances in each trip, the use of electricity for fuel has a long way to catch up to that of gasoline.

Climate/Seasonal Variations

San Diego didn't provide a very good opportunity to evaluate the impact from climate or seasonal variations on charging infrastructure utilization as average monthly high temperatures go from 65° to 77° over the year, and the high to low daily temperature difference is no more than 17°.

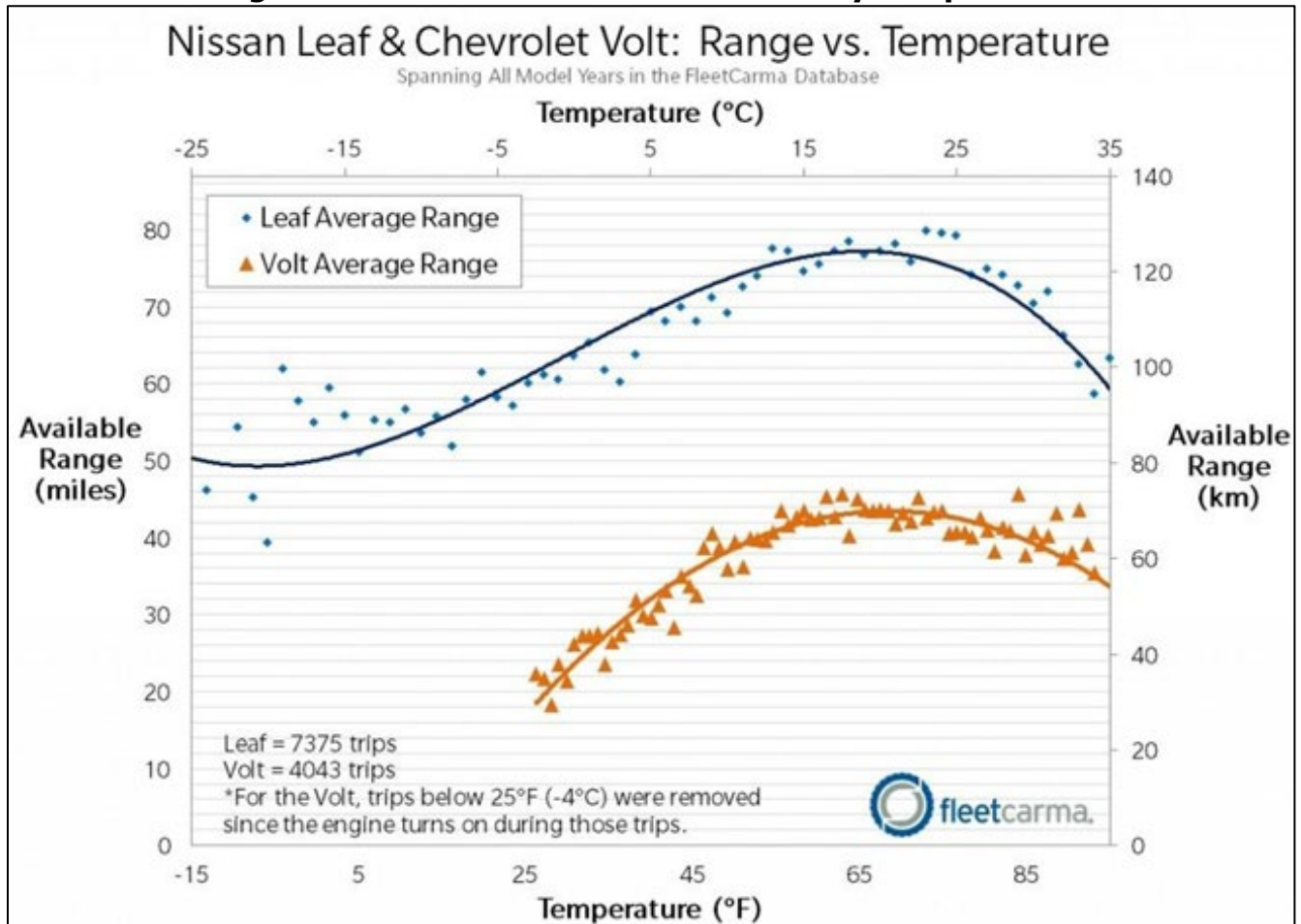
FleetCarma, a Canadian company, has used its mobile application, MyCarma, to track PEV usage during seasonal variations in Ontario. Based on their results, PEV batteries perform at their peak within temperature ranges from 60 – 75 degrees. Hotter climates, as well as colder locations have a direct impact on vehicle range.

The Volt had fewer reports of variations in its battery life compared to the Leaf; however, drivers not completely relying on the all-electric feature could have caused this. Nissan is working to develop a battery that is more tolerant to heat with a release date potentially approaching before the end of 2014¹⁶. Figure 101 is a result of this study.

¹⁵ [San Diego Traffic Report](http://www.hribar.com/san-diego-traffic-report.html) <http://www.hribar.com/san-diego-traffic-report.html> [Accessed April 22, 2013]

¹⁶ [Nissan Leaf, Chevy Volt Range Loss In Winter: New Data From Canada](https://www.greencarreports.com/news/1089160_nissan-leaf-chevy-volt-range-loss-in-winter-new-data-from-canada) https://www.greencarreports.com/news/1089160_nissan-leaf-chevy-volt-range-loss-in-winter-new-data-from-canada [Accessed April 10, 2014]

Figure 101: Leaf and Volt Performance by Temperature



Source: Green Car Reports

Availability of Vehicle Chargers

The latest results from the PEV Owner Survey, a collaborative research project managed by the California Center for Sustainable Energy, shows differences in the results from the previous survey in driver satisfaction with publicly available EVSE and vehicle use trends. The February 2014 Report¹⁷ involving 57 percent Leaf, 17 percent Chevrolet Volt and 22 percent Toyota Prius Plug-ins show an increase in driver satisfaction with publicly available and workplace EVSE. Between findings in March of 2012 and March 2013, drivers reported an increase from 14 to 46 percent of available workplace charging stations. Driver satisfaction with the availability of publicly available infrastructure rose from 17 to 29 percent. In addition to charging at home, 71 percent of PEV owners report access to either public or workplace charging or both. In addition, the Report identifies that the current electric vehicles in the state save approximately 350,000 gallons of petroleum every month.

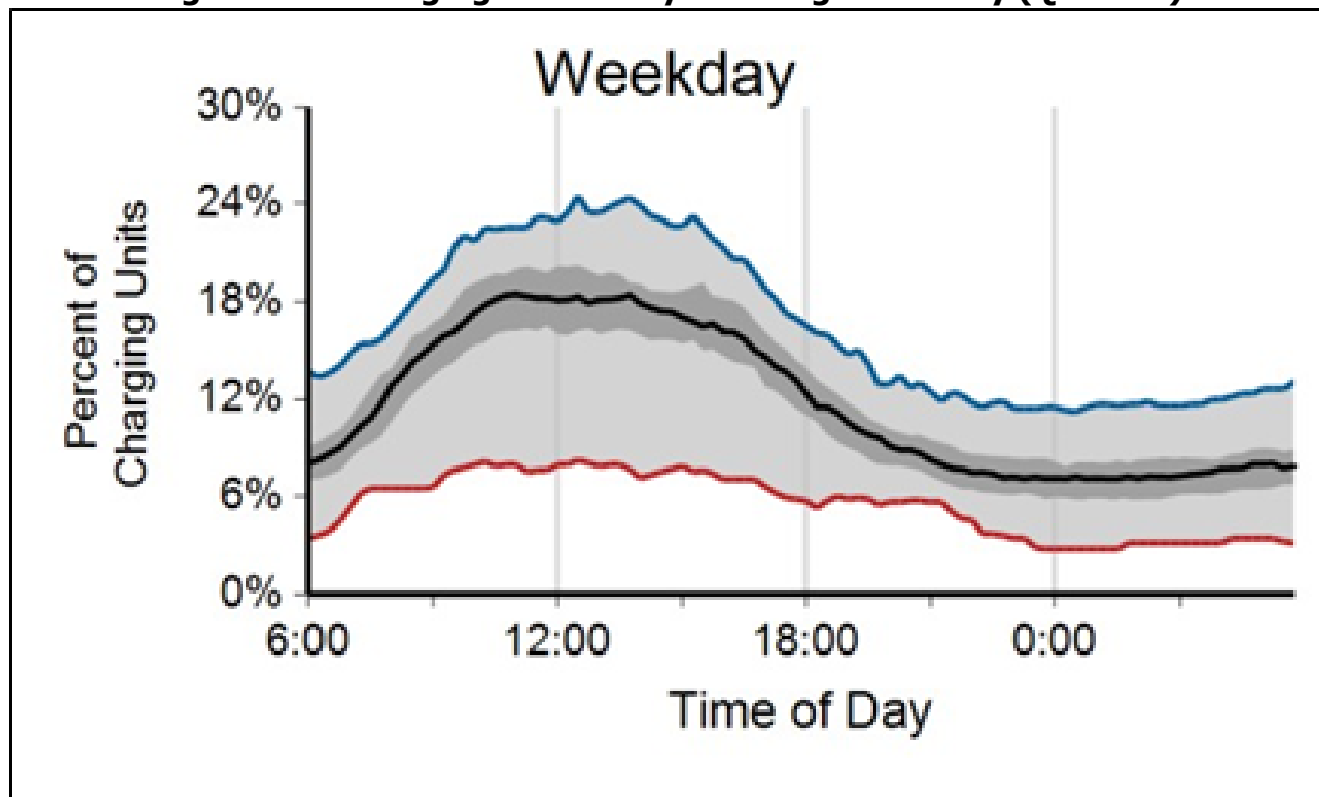
Chapter 4 provided observations on the utilization of publicly accessible EVSE. Acceptance and local enthusiasm over the use of these EVSE is evident in San Diego (and San Francisco

¹⁷ [California Clean Vehicle Rebate Program](http://www.energycenter.org/clean-vehicle-rebate-project/vehicle-owner-survey) <http://www.energycenter.org/clean-vehicle-rebate-project/vehicle-owner-survey> [Accessed April 10, 2014]

and Los Angeles as well). Figure 102 reviews the charging availability of publicly accessible EVSE in the San Diego region in the fourth quarter 2013. Charging availability is the percent of publicly accessible EVSE that are in use at any one time. The hourly profile for each day in the quarter is overlaid on the same axis to reveal the associated time-of-day plot. It is provided again here to identify that even with this enthusiasm, at most, 24 percent of the publicly accessible EVSE were in use at any one time in the quarter. At some time during the quarter, the minimum percent of EVSE in use at any one time during the peak of the day was about 7 percent. In other words, between 76 and 93 percent of the publicly accessible are unused at the peak usage times of the day. In general, the EVSE are indeed available to the public.

As noted earlier in the utilization observation, the public surveys and opinions suggest that the PEV driver will utilize publicly accessible EVSE. Several reasons may exist on why these EVSE are largely unused (even though usage is higher than other locations within the EV Project). Further study on this subject is warranted.

Figure 102: Charging Availability San Diego Weekday (Q4 2013)



Source: Blink Network

Operating Cost

In addition to the costs associated with purchasing EVSE, companies that wish to make workplace charging available to employees and retail businesses will incur further costs in operating and maintaining EVSE. The California Department of General Services recently

published "*Electric Vehicle Supply Equipment Guidance Document*"¹⁸ to assist facility and fleet managers in the planning, budgeting, installation, and data collection of electric vehicle supply equipment. It provides guidance and estimates for equipment and installation costs for the different EVSE designs. Maintenance costs vary based on the EVSE design with the more sophisticated Smart EVSE requiring more maintenance than a basic EVSE. Some business models provide for a third party to maintain the equipment. That reduces the operating cost to the host.

The utilization study suggested above is important to further promote the expansion of the publicly accessible infrastructure. A charging site host will need to understand the financial incentive to providing the charge infrastructure for its customers. The acquisition and installation costs overshadow the operating costs (with the exception of DCFC demand charges discussed in Section 5.7) so the financial benefit to the host must be in increased store traffic and stay times. Revenue sharing programs for the access fees may be important to some but if it can be shown that a PEV driver will stay longer in the store (because the vehicle is charging) or preferentially stops at a location providing public EVSE or returns more often, the host will be motivated to absorb the associated costs. Prior to the bankruptcy, ECotality had commenced a study of national accounts that provided anecdotal information that such was the case. These retailers know the average purchase amount by time in the store so if that time can be lengthened, it results in greater sales. This study would be valuable in understanding this question.

Although this infrastructure study did not include an extensive evaluation of workplace charging, the deployment of workplace charging infrastructure from this project will enable further study while it promotes the adoption of PEVs.

Influence of Time of Use Rates

The electric utilities serving the EV Project regions have a mixed response to addressing the impact of PEVs on their local grid. Some have shown little concern as yet for overall power generation and distribution in their service territory while others see the increase in PEV charging demand as an additional challenge to an already challenged system. This is particularly true in the southwestern states where there is a history of power disruptions in the grid - so called "brownouts" and "blackouts".

Electricity generating costs to the utility can be reduced if the peak demand is lowered by shifting some demand to the other times of the day. To do this, the electric utility, through approved rate designs, may provide time-of-use (TOU) rates that incentivize power users to shift their loads if possible. SDG&E has such TOU rates but not all utilities have such rates.

The project published a report comparing the impact in San Francisco (Pacific Gas & Electric) with TOU rates to that of Nashville (Nashville Electric Service). That report: "*How do PEV owners respond to time-of-use rates while charging EV Project vehicles?*"¹⁹

¹⁸ [Electric Vehicle Supply Equipment Guidance Document](http://www.government-fleet.com/fc_resources/pdf/evse-guidance-document-01-28-14.pdf) http://www.government-fleet.com/fc_resources/pdf/evse-guidance-document-01-28-14.pdf [Accessed April 10, 2014]

¹⁹ [How do PEV Owners Respond to Time-of-Use Rates While Charging EV Project Vehicles?](https://avt.inl.gov/sites/default/files/pdf/EVProj/125348-714937.pev-driver.pdf) <https://avt.inl.gov/sites/default/files/pdf/EVProj/125348-714937.pev-driver.pdf> [Accessed April 10, 2012]

The following compares the grid impact for SDG&E to that of Nashville Electric Service assuming the background information of the reference.

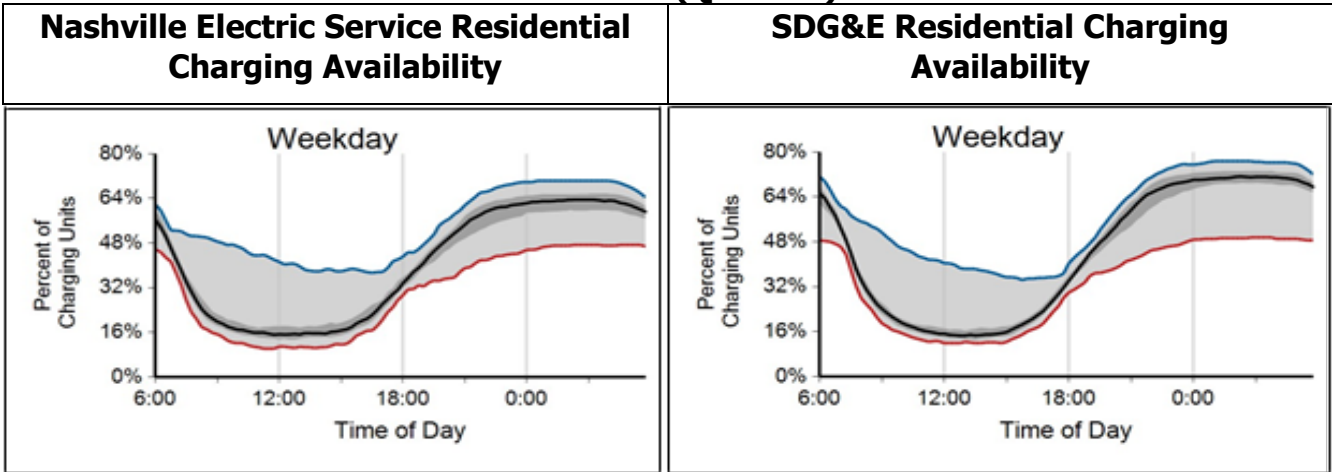
The methodology of the comparison utilizes “Charging Availability” and “Charging Demand”.

Charging availability at a point in time is the percentage of EVSE in a geographical area that are connected to a vehicle. Charging demand at a point in time is the total amount of power drawn from the electric grid by a group of EVSE in a geographical area. Time-of-day plots represent these data. For the EV Project, these plots are in the quarterly reports posted on the website.

They are prepared by geographic area and show the hourly percentage of EVSE connected and hourly charging demand for all weekdays and weekends for the quarter evaluated.

Figure 103 shows the weekday residential charging availability for participant vehicles in the Nashville Electric Service and SDG&E territory during the fourth quarter 2013. Note that the plots show the maximum, minimum, median and inner quartile values for all the days of the quarter.

Figure 103: Charging Availability in Nashville Electric Service and SDG&E Service Territories (Q4 2013)

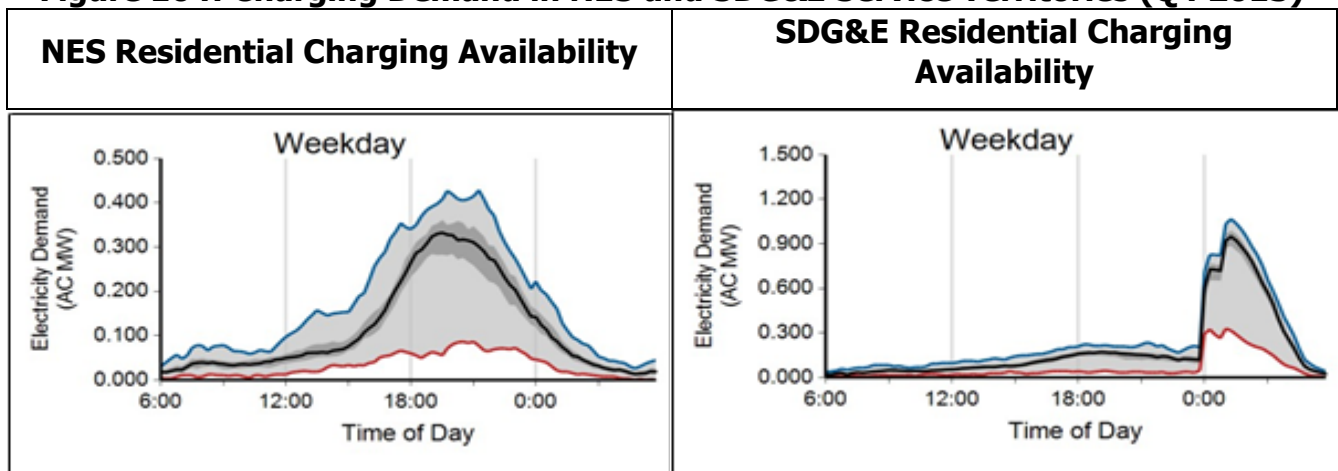


Source: Blink Network

Driver behavior is nearly identical in these territories. In aggregate, the driver connects the vehicle to the residential EVSE upon returning home.

However, Figure 104 shows the difference in vehicle charging impact.

Figure 104: Charging Demand in NES and SDG&E Service Territories (Q4 2013)



Source: Blink Network

The charge demand in NES service territory coincides with the vehicle connect times. Thus, the charge commences as soon as the vehicle connected. While the drivers in San Diego also connect when arriving home, they delay the vehicle charge until midnight or shortly thereafter. Both the EVSE and the vehicles provide charge programming capabilities to accomplish this delay. Thus, the TOU incentive does influence PEV driver charging behavior.

This incentive may create other peak demand issues for the utility. As the paper referenced above also points out, TOU incentives can be more effective in some service territories than others either by not providing a large enough incentive to move all behavior or in the lack of public knowledge of these special rates. This may be by design by the utility to prevent the creation of another spike issue.

The project conducted a survey on this topic in the PG&E and Portland General Electric service territories. The above referenced paper also reports the results of this survey. Until the survey was distributed, 3 percent of the PG&E responders said that they were not aware their utility provided TOU rates and 13 percent of the Portland General Electric customers said that they were likewise not aware. Sixty-seven percent of the PG&E responders indicated that they changed rates during or after they acquired the PEV. Only 31 percent of the Portland General Electric responders indicated that they changed. However, the participant largely educated themselves of the TOU rate. 75 percent of the PG&E and 72 percent of the Portland General Electric responders said they found the rate for themselves.

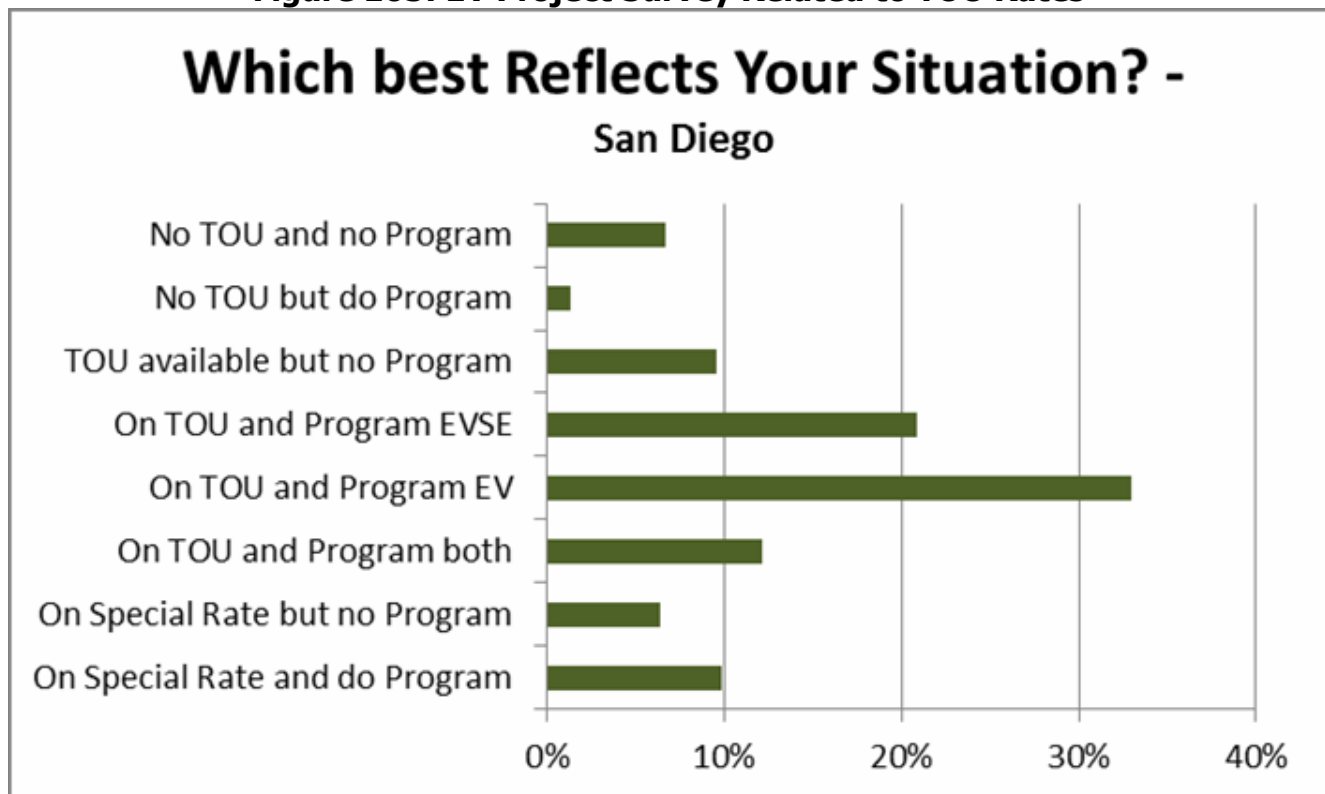
The survey of participants also included questions on the awareness of TOU rates and how the participant responds to them. Whether the respondent programmed the EVSE or the PEV was also of interest. Figure 105 shows the response from those in the San Diego area.

The possible responses were:

- My electric utility does not provide TOU rates and I don't program my charging unit or EV
- My electric utility does not provide TOU rates, but I program either my charging unit or EV to start at a specific time anyway

- My electric utility does provide TOU rates, but I don't program my charging unit or EV
- I am on the TOU rate for my electric utility and I program the EVSE only
- I am on the TOU rate for my electric utility and I program the EV only
- I am on the TOU rate for my electric utility and I program both the EV and EVSE
- I am on a special rate with my electric utility (such as home solar) and I don't program the charging unit or EV
- I am on a special rate with my electric utility (such as home solar) and I do program either the charging unit and/or the EV

Figure 105: EV Project Survey Related to TOU Rates



Source: Blink Network

Smart Charging and Smart Grids

A presentation at the Institute of Electrical and Electronics Engineers Transportation Electrification Initiative and Arizona State University's LightWorks Lecture in Scottsdale Arizona reported new challenges to SDG&E with the adoption of PEVs and distributed generation, most of which is photovoltaic. This presentation, "*San Diego Electric Vehicles Growth*"²⁰ emphasizes the need for smart charging to support its smart grid.

With upgrades needed to provide larger coverage for smart grid technology, and the incorporation of higher end smart charging stations, SDG&E will have greater control over the distribution of PEV charging. Smart EVSE will charge during the hours where renewable

²⁰ [San Diego Electric Vehicles Growth](https://tec.ieee.org/newsletter/march-april-2014/san-diego-electric-vehicles-growth) <https://tec.ieee.org/newsletter/march-april-2014/san-diego-electric-vehicles-growth> [Accessed April 10, 2014]

energy is operating at its peak, and then again during the late-night hours when demand is at its lowest. SDG&E will be able to monitor and control charging behaviors during these times.

As discussed in Chapter 3, the use of networked vehicle charging infrastructure like the Blink network, provides a method by which utilities and electricity users can work together to mitigate the demand for energy when it is not essential to have it “right then”. Now that the technical ability to execute this demand reduction method has been established for residential users, the next challenge will be to manage non-residential charge units in a similar way.

Amongst the possibilities would be making the chargers unavailable during high demand periods, reducing the energy delivered, or charging a premium in order to control demand whilst not stranding a motorist who may have a critical need to charge their vehicle.

Supporting New Technology Advancement for Vehicles to Promote Deployment

The CEC published the “*2013-2014 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program*”²¹ in May 2013 to identify their investment plan for further funding to support California’s goals for alternative fuel use. The Zero Emission Vehicle Action Plan sets a goal of putting 1 million zero-emission vehicles on the road by 2020 and 1.5 million by 2025. Each year the CEC puts together an investment plan to help California reach these goals. The CEC provides up to \$100 million a year in grant money to support the adoption and use of alternative fuel vehicles. Additional goals include air quality improvement by lowering the amount of GHG emissions, supporting renewable fuels by providing sufficient infrastructure and funding the advancement of vehicle technology and design.

Extrapolating from the data cited above, the infrastructure deployed in this project supported about 18.3 million miles of electric travel through December 2013. This project also supported the development of networked charging technology as they did not really exist prior to this project. Now there are internet sites and cellphone applications to help EV drivers locate chargers and if the chargers are networked, they will probably know if the chargers are available or in use. Through this project, the capability of this networked charge infrastructure has also shown that it can be used to manage energy demand.

Other technology supported as a result of this project has been through the use of EVs. The project helped to fund the new cost of a “personal fueling unit” in your garage or at your favorite retail store, which in turn encouraged early adopters to buy and ultimately to drive PEVs. This data will lead to improvements in charge infrastructure through cost reduction, feature enrichment, and access technology convergence.

Incorporation and Achievement of Sustainability Goals

The adoption of PEVs promotes several sustainability goals. Reducing reliance on foreign oil, reducing gasoline consumption and reducing the production of greenhouse gases in the transportation sector are frequently identified goals. PEVs provide a means to achieve these

²¹ [2013-2014 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program](http://www.energy.ca.gov/2012publications/CEC-600-2012-008/CEC-600-2012-008-CMF.pdf)
<http://www.energy.ca.gov/2012publications/CEC-600-2012-008/CEC-600-2012-008-CMF.pdf> [Accessed April 10, 2014]

goals. The adoption of PEVs is still in its infancy. It is important to remember that the current generation of PEVs was first introduced in late 2010. With barely three years' experience, the adoption rate continues to grow along with new manufacturers adding more vehicles each model year (over 200,000 modern highways capable PEVs sold to date, and 9,000 in April 2014 alone according to [HybridCars](http://www.hybridcars.com) (www.hybridcars.com)). The market penetration of PEVs is still small but growing. The benefits of this growth are identified in terms of reduced petroleum usage, reduced fuel operating costs, energy consumed and greenhouse gas reduction.

The EV Project and others provided estimates of the potential growth of the PEV penetration in the early days of the project, but it was largely speculation. Data now exists on the adoption in many sectors, and projections can now be based on real-world data collected. The information presented in this report on per vehicle savings in all these areas along with the projections of PEV adoption provide data to the sustainability planners on the future impact of PEV adoption.

Benefits to California

The EV Project was a national program involving municipal areas in many states. Three municipalities in California were included. As such, the project directly provided benefits to California. This section explores some of these benefits.

California Job Creation

The US DOE supported the EV Project with grants funded from the American Recovery and Reinvestment Act of 2009 (ARRA). As an ARRA-funded project, one of the primary goals of the EV Project was to create or retain jobs.

By "job", ECOtality determined the "level of effort" required to design, develop, manufacture, and install ESVE as well as administer and analyze the entire process. Each type of EVSE station (residential and non-residential AC Level and DCFC) required analysis of the level of effort in man-hours. Multiplication by the number of EVSE stations of each type planned for each state, as defined in the EV Project rollout plans, yielded the projected "jobs". Fifty-two weeks of work at 40 hours per week results in a full time equivalent (FTE) of 2,080 hours per year. One "job" then is defined as one FTE.

Many of the jobs created by the EV Project occurred in the participating states while other jobs occurred in states where the EVSE and DCFC were manufactured or warehoused. In California, direct jobs were created in the selection of Area Managers in San Diego, Los Angeles and San Francisco as well as the office staff and construction management team hired by the EV Project from locally found talent. Additional jobs were created in the hiring of the local contractors to conduct the installation of these EVSE.

EV Project Employees:

The Area Office was created in the San Diego region in February 2010 with the employment of the Area Manager; followed shortly thereafter by the office administrator and field services construction superintendent. These full-time employees continued to mid-year 2013. Additional personnel were added to the staff for part of this time to enlist charging site hosts and manage the local contractors. In addition, this regional office staff and this project were supported by personnel located in the Phoenix area. This provides a total of 15 FTEs.

EVSE Installations in San Diego County:

Chapter 4 provides information on installation costs for a cost study conducted prior to the completion of the deployment of non-residential AC Level 2 EVSE. At the time, 264 units were installed in 43 sites at an average of \$9,329.62 per site and \$1,519.60 per EVSE. The ratio of EVSE to site was 6.14.

At the end of the project, there were 552 total EVSE in 170 sites for a ratio of EVSE to site of 3.2. Extrapolating the previous study for the final installations yields a total installation cost of approximately \$1,145,000. The same contractor rate of \$50 per hour requires 22,900 hours which implies 11 FTEs.

The 22,900 hours spent to install 552 EVSE implies approximately 21.6 hours for two tradesmen or 2.7 days required to install each EVSE. Considering the complexity, permitting/inspection time, AHJ reviews, etc., this appears to be a reasonable estimate.

DC Fast Charger Installation

The total cost for installation of the four DCFCs was \$92,100. The same contractor rate of \$50 per hour implies 1,842 hours required for installation or approximately 1.0 FTE.

Three to four different trades typically conduct such installations which implies approximately 21 days per site to complete installation or about 4 weeks each unit of actual construction time. The installations were very complex, and many days were required in addition waiting for approvals.

In summary, the project directly provided at least 27 direct FTEs in California.

Indirect Benefits

The employment of persons in San Diego created indirect employment. Such activities result in the creation of “indirect jobs” that can be estimated using modeling. ECOTality used *Updated Employment Multipliers* (2003) by Dr. Josh Bivens²² to assist in the early projections of jobs created.

The indirect employment (or employment multipliers) associated with jobs in any given industry results from three effects: supplier effects, re-spending effects, and government employment effects. Supplier effects are impacting that job-creation or destruction in an industry has on supplier industries. For example, when an automobile plant closes, this will affect (among other things) the steel industry jobs that supply materials to the auto plant. Re-spending effects are the impacts that job creation or destruction in an industry has on those sectors where workers spend their paychecks. For example, when an automobile plant closes, this will affect (among other things) the apparel industry that supplies the clothes that workers from the auto plant used to spend their wages on.

Government employment effects refers to the taxes that support jobs in federal, state, and local government; if workers in private industries lose their jobs, this erodes the tax base that

²² [Updated Employment Multipliers](http://pbadupws.nrc.gov/docs/ML1224/ML12243A398.pdf) <http://pbadupws.nrc.gov/docs/ML1224/ML12243A398.pdf> [Accessed April 23, 2014]

supports government employment. Additional benefits accrued to the State and local governments through the wages paid to these employees and contractor earnings.

The reference reports show that employment multipliers are much larger in manufacturing than also reports that the largest employment multipliers include automobiles. In the reference reports it shows that for every 100 direct jobs, approximately 230 jobs in materials suppliers, 50 jobs in capital services, 171 jobs in re-spending employment and 12 jobs in state and local government are supported.

Although manufacturing of the EVSE deployed in the EV Project occurred outside California, some component parts did originate in California. In addition, the material required in the installation process, such as conduit, conductors, breakers, etc. were purchased locally and supported local jobs.

Assuming the above ratios, the 27 direct jobs in California then would support 62 supplier jobs, 13 jobs in capital services, 45 jobs in re-spending employment and 3 jobs in state and local government. The resultant impact on jobs in California is 150 jobs supported directly and indirectly.

Petroleum Use Reduction

Petroleum use reduction is included in goals in federal, state and local governments. Not only does this support reduction of greenhouse gases (GHG) but results in lower operating costs for PEV drivers. The EV Project deployment of PEVs resulted in Leaf vehicles that totally utilize the internal battery for motive power and Volts that operate a significant amount of travel on their internal battery. The following explores the gasoline saved and the resulting reduction in fuel cost.

Petroleum Use Reduction

The total miles driven by Leaf owners through the end of December 2013 was 89,175,939 miles. The total miles driven in EV Mode were approximately 22,960,000 miles. The Car2Go vehicles traveled a total 2,906,168 miles. These miles displaced miles that internal combustion vehicles would have generated during the same period.

Approximately 45 percent of every barrel of crude oil refines to gasoline. Since the barrel contains about 42 US gallons, each barrel of crude produces 18.942 gallons of gasoline.²³

Nissan Leaf

An internal combustion vehicle equivalent to a Leaf would typically record 28.6 miles per gallon. Thus, the travel throughout the EV Project resulted in the avoidance of 3,118,040 gallons of gasoline or 164,610 barrels of oil.

The current annual mileage for the Leaf is 6,500 miles so on average, each Leaf saves approximately 227 gallons of gas or 12 barrels of oil per year. 681 of the EV Project Leafs operate in the San Diego region. They contributed about 12,500,000 miles to the project. Thus, their travel in the EV Project resulted in the avoidance of 437,000 gallons of gasoline or 23,070 barrels of oil.

²³ [U.S. Energy Administration Information www.eia.gov/](http://www.eia.gov/) [Accessed April 23, 2014]

SmartForTwo

An internal combustion vehicle equivalent to the SmartForTwo vehicle would typically record 36 miles per gallon. Thus, the travel by the SmartForTwo vehicles throughout the project resulted in the avoidance of 80,730 gallons of gasoline or 4,262 barrels of oil.

The final 416 SmartForTwo vehicles were added in increments throughout 2012 and 2013 so on average, the contribution of each is 3,500 miles per year. Thus, on average, each car sharing vehicle saves approximately 97 gallons of gasoline or 5 barrels of oil annually.

386 of the 416 SmartForTwo vehicles are in use in the San Diego region. On average, the use of these vehicles has resulted in the avoidance of 75,000 gallons of gasoline or 3,955 barrels of oil.

Chevrolet Volt

An internal combustion vehicle equivalent to the Volt vehicle would typically record 31.7 miles per gallon. Thus, the travel by the Volt vehicles throughout the project resulted in the avoidance of 724,290 gallons of gasoline or 38,237 barrels of oil.

The current annual mileage for the Volt in EV Mode is 7,750 miles so on average, each Volt saves approximately 244 gallons of gas or 13 barrels of oil per year.

Two hundred seventy-two of the EV Project Volts operate in the San Diego region. They contributed about 3,088,000 electric miles to the project. Thus, their travel in the EV Project resulted in the avoidance of 97,400 gallons of gasoline or 7,145 barrels of oil.

Table 12 summarizes the above information.

Table 12: Estimated Gasoline Saved by PEVs in EV Project

Vehicle	Gasoline Saved Nationally in EV Project (gallons)	Gasoline Saved San Diego in EV Project	Average Annual Mileage	Estimated Average Annual Gasoline Saved per Vehicle
Leaf	3,118,040	437,000	6,500	227
Volt	724,290	97,400	7,750	244
SmartForTwo	80,730	75,000	3,500	97

Source: Blink Network

The number of PEVs in the San Diego area continues to grow past the end of the EV Project. For each new vehicle added, a significant reduction in petroleum occurs. Even though the PHEV offers the driver the extended range to provide range confidence of an ICE, as stated earlier the drivers in San Diego accumulate 74 percent of their Volt miles in EV only mode.

Cost of Fuel

The cost of the fuel to power the vehicle is a natural follow-on question. Cost reduction occurs because the cost of electricity is much less than the cost of gasoline and PEVs are

more efficient than conventional ICE vehicles. The Leaf requires approximately 340 Watt-hours/mile, the Volt 360 and the SmartForTwo 390. The travel identified in the Section above leads to the calculation of energy required to provide this travel.

Once the energy requirements are known, the cost of this energy becomes a more complex issue. Most of the charging occurs at home and most of that during off-peak times. SDG&E provides special TOU rates to encourage the off-peak charging. However, approximately 20 percent does occur away from home and would be subject to the commercial or industrial rates for the workplace, fleet or publicly accessible EVSE. The detailed analysis to identify how much charging occurred at each location and the specific rate in effect at the time is beyond the scope of this report. In addition, some hosts and employers provide away-from-home charging at no cost to the PEV driver. Therefore, it is assumed that all energy is consumed at the SDG&E Tier one, baseline rate of \$0.14/kWh.²⁴

The cost of gasoline has also widely varied throughout the project. At this writing, the cost of gasoline in San Diego is \$4.264 per gallon. Using these factors, Table 13 shows the costs for annual PEV or the equivalent ICE vehicle travel in San Diego.

Table 13: Annual Fuel Costs for PEV vs ICE vehicles in San Diego

Vehicle	Annual Miles	Electric Cost	Gasoline Cost
Leaf	6,500	\$309.40	\$969.09
Volt	7,750	\$390.60	\$1,045.76

Source: Blink Network

The economic benefit for utilizing the PEV is obvious. It is also a clear motivation for Volt drivers to utilize as much of their travel in EV Mode as possible.

Greenhouse Gas Emission Reduction

The analysis of gasoline and greenhouse gas avoided by the use of electric vehicles is the subject of a lessons learned document "*Greenhouse Gas Avoidance and Cost Reduction*"²⁵ posted to the EV Project website and forms the basis for the calculations that follow.

The GHG emissions avoided occur due to the difference in emissions associated with power plant electricity generation versus fuel combustion that occurs in the engine of a conventional vehicle. The analysis presented here does not account for life-cycle emissions that occur outside of electricity generation and fuel combustion phases (i.e., materials and resource extraction, production supply-chains, and decommissioning are not accounted for). These phases are beyond the scope of this report due to the significant effort required to conduct an accurate environmental life-cycle assessment for a transportation system in a very specific setting.

²⁴ [SDG&E Rates](https://www.sdge.com/total-electric-rates) <https://www.sdge.com/total-electric-rates> [Accessed April 23, 2014]

²⁵ [Greenhouse Gas Avoidance and Cost Reduction](https://avt.inl.gov/sites/default/files/pdf/EVProj/106077-891082.ghg.pdf) <https://avt.inl.gov/sites/default/files/pdf/EVProj/106077-891082.ghg.pdf> [Accessed April 23, 2014]

Nationally, GHG emissions in the production of electricity are 1.53 lb-CO₂e/kWh.

Calculations for GHG emissions in the San Diego region consider the local mix of generation by the electric utilities. The EPA collects and publishes a comprehensive source of data on the environmental characteristics of power generated in the United States in the Emissions & Generation Resource Integrated Database (eGRID).²⁶ The most recent published data is for year 2010.

In the SDG&E service territory, there are several local and municipal utilities. While energy is also obtained from sources outside San Diego County, only generation within the SDG&E service territory (which includes the EV Project boundary) is considered for simplicity. The total net plant annual generation in the service territory in 2010 was 7,911,301 MWh. The total plant annual CO₂, CH₄ and N₂O emissions totaled 3,552,884 tons. This implies a total annual emissions rate of 898.18 lb-CO₂e/MWh or 0.898 lb-CO₂e/kWh.

The GHG emissions (in pounds of carbon dioxide equivalent (which accounts for other GHGs such as methane and nitrous oxide), lb-CO₂e) from combustion of gasoline is 20.1 lb-CO₂e/gallon.²⁷

The CO₂e avoided by the EV Project then is the CO₂e that would have been generated by petroleum use minus that consumed by the PEVs from the generation of that energy. Table 14 provides these figures for the entire EV Project, San Diego portion and the annual benefits from the vehicles involved.

Table 14: Estimated Avoided GHG Emissions

Vehicle	Total CO₂e Avoided Nationally in EV Project (lb-CO₂e)	Estimated Total CO₂e Avoided San Diego Area in EV Project (lb-CO₂e)	Annual Miles	Estimated CO₂e Avoided Annually (lb-CO₂e)
Leaf	16,283,000	4,968,500	6,500	2,584
Volt	1,91,000	959,400	7,750	2,409
SmartForTwo	N/A	561,500	3,500	728

Source: Blink Network

The average annual miles driven by the Leaf and the Volt avoid over 1 ton each in GHG emissions.

²⁶ [U.S. EPA Energy and Environment Website](http://www.epa.gov/cleanenergy/energy-resources/egrid/) <http://www.epa.gov/cleanenergy/energy-resources/egrid/> [Accessed April 27, 2014]

²⁷ *Greenhouse Gas Avoidance and Cost Reduction op cit.*

Lessons Learned

The EV Project published numerous white papers and lessons learned documents. Many reported specifically on the San Diego market, but most are applicable to the San Diego region. Some of these are discussed earlier in this report and more information is provided below for those that included analysis specifically associated with the San Diego market.

Electric Vehicle Public Charging – Time vs. Energy

Early in the EV Project discussions concluded that while free access to commercial charging infrastructure provides an effective means of initializing infrastructure use, it does not support a “viral” expansion of charging infrastructure. Widespread deployment of charging infrastructure at commercial locations must either be subsidized, or it must generate sufficient income to provide a return on the investment made by the infrastructure owner. It is assumed that a small amount of charging infrastructure may be subsidized by local, State or Federal government funding its installation, and some businesses may choose to subsidize it by providing free charging as an enticement to attract customers. However, the quantity of charging infrastructure necessary to support widespread adoption of PEVs must be supported by private investment, anticipating a return. Access fees provide one mechanism to provide this return on investment.

The EV Project survey of participants and other anecdotal remarks show that drivers will utilize free charging provided in public or by employers and thereby reduce their home charging needs. The effect is to shift some charging from the off-peak periods at home to the on-peak periods at work.

With the decision then made that access fees are necessary, on what metric will the fee be based? The EVSE deployed in the EV Project was smart equipment that could be programmed over-the-air to support three means for collecting access fees: fees based upon time connected to the unit for the charge; fees based upon the energy used measured in kilowatt hours; or fees based upon a subscription wherein all in-network charging is included in a monthly fee.

It was intended that the EV Project would test several models but could not complete such before the bankruptcy. However, the first phase of implementing access fees was based upon time connected.

Time based access fees are applied to the user of the charge infrastructure for all time that the vehicle is connected to the charge unit. This is regardless of whether or not there is energy being delivered or the rate at which it is delivered. Once authorized to charge and connected to the vehicle, the charging costs accumulate in increments of time, and continue until the charge is stopped or interrupted. The total cost reflects the total time that the vehicle had access to the charging station.

An occupied EVSE is not available for others to use. Other payment systems do not limit the time a driver may remain connected and thus deny the host from receiving potential revenue. As has been seen in this report, a vehicle may quickly restore the battery capacity in public charging after which time, there is no cost for the driver to remain if the fee is based upon energy delivered. Billing by time is evident to the driver who will know exactly what the fee will be. The actual energy delivered to the vehicle is dependent upon many factors including the vehicle battery’s state of charge, temperature and capabilities of the on-board charger

and battery management system. It is not possible to know and fully inform the EV driver what the final fee for the charge will be.

At the time of the decision, several states were considering whether the EVSE was delivering electricity and thus should fall under utility regulations. Charging a fee based upon the energy delivered appeared to support this view. This would also appear to require an energy meter that was capable of certification by a state's weights and measures department and EVSE design to permit the removal and replacement of this device for testing. However, the time-based fee system avoided these issues and treated charging as it is – a public convenience. The driver is paying for the convenience of being able to charge away from home. The initial fee structure was based upon hours connected.

There are situations where an hourly fee may not be the best choice, however. An EVSE located at a Park and Ride location would be expected to host a single driver for the entire day. A fee in this case may best be assessed as a fixed fee for the day. Such may also be the case for parking at an employer or multi-family location.

The EV Project had just begun to provide access cards and EVSE programming that would allow multiple methods for access control and fees. Based upon the membership, the EVSE would allow charging by fleet users in unlimited quantities and bill the fleet owner monthly while at the same time provide time-based charging for the general public. Such methods meet the needs of several customers at the same time.

This paper presents an argument that the benefits of consistent pricing and a pricing structure that encourages sharing of the infrastructure make charging by time a better option. Since publishing this paper, the industry has moved more toward a homogenous solution. While still in the development phase, the National Institute for Standards and Technology (NIST) is working toward a standard associated with vehicle charging that requires some form of measurement of energy delivered but does allow for additional charges to be made (e.g. for time spent at the charger).

Accessibility at Public EV Charging Locations

As noted in Chapter 3, no federal guidelines existed at the start of the EV Project related to providing accessibility at public EVSE. Consequently, the EV Project published its own guidelines after an extensive search and study of this question. The EV Project was uniquely qualified to conduct this evaluation because it not only had the responsibility for the design of the stations and the design of the EVSE, but it also employed the contractors and had experience doing the installations. An important factor missing in all local attempts at identifying compliance guidelines was the cost of implementation.

Typically, the cost for compliance is not material to the evaluation of the compliance and in most cases, does not have significant impact on the project. The EV Project report summarized the ADA requirements for product design and parking and provided the following:

The general requirements for accessibility can be applied to EV charging stations. A person with disabilities utilizing an accessible EVSE parking space must be able exit their vehicle, enter a side access aisle to access the EVSE, operate the charging station, insert the EVSE

connector into the EV and access the services on-site. In addition, the EVSE must comply with the specific ADA requirements for height and operation.

Tied into the question of accessibility is exclusivity. Should the parking stall in which the EVSE is located be exclusive for PEV charging? Charging is a distinction that is important because the EVSE is for charging; not PEV parking. If it is exclusive and marked for disability access only, it cannot be counted as one of the ADA accessible spots required of the parking in general.

Implementing the requirements in new construction is not difficult. However, a retrofit of an existing facility quickly can run into difficulties and high costs. The parking lot was engineered to meet the ADA parking requirements and to take another spot specifically for PEV charging may be detrimental to the business.

In general, handicap accessible parking spots are close to the facility entrance but placing EVSE there may greatly increase installation costs. As noted previously in this report, one of the high cost drivers for installation is distance from the electrical source and any concrete and asphalt cuts. Implementing the path and slope requirements in an existing parking lot may also be costly.

Consequently, the EV Project identified existing rules in the ADA regulations: Subpart D of 28 CFR Part 36 concerning disproportionate costs associated with the design and installation of improvements to a parking area. Specifically, 36.403(f) provides:

In addition, this section identifies examples of costs that may be considered including "costs associated with providing an accessible entrance and an accessible route to the altered area, for example, the cost of widening doorways or installing ramps;...and costs associated with making restrooms accessible, such as installing grab bars, enlarging toilet stalls,..."

The reference to enlarging toilet stalls as an example would infer costs associated with widening of a parking space could be included. If the cost to widen a parking space and the associated changes to the parking lot exceed 20 percent of the cost of the alteration to the primary function area, the cost would be disproportional.

The EV Project did encounter situations where the local AHJ's interpretation of the ADA requirements was overly restrictive and some charging site hosts declined to participate. The EV Project also found situations where the local AHJ had no interest in whether the site design met any ADA issues in the absence of federal guidelines.

This issue remains unresolved but needs to gain federal guidance to avoid continued problems with publicly accessible EVSE installations.

Signage

During the development of the local deployment guidelines documents in several of the EV Project regions, the advisory groups struggled with signage. All agreed that signs needed to be posted at the EVSE for EV Charging Only but what symbol should be used. All felt it was desirable to identify a single symbol that would eventually be recognizable to all. However, several parts of the U.S. had already considered their individual signage and some had obtained patents on certain designs. The five original regions of the EV Project agreed on the symbol as identified in the Manual of Uniform Traffic Control Device published under 23 Code

of Federal Regulations (CFR) Part 655, Subpart F. Two of the locations submitted a request for the Federal Highway Administration to approve interim approval of the Manual of Uniform Traffic Control Device design which it did. Figure 106 shows the approved design.

Figure 106: Federal Highway Administration Interim Approved Symbol



Source: US Department of Transportation

The California PEV Collaborative later endorsed the same symbol and recommended its use in California.

The complete document is included as Appendix BB and includes more information on signage for dedicated parking and considerations for imposition of penalties for non-compliance.

DC Fast Charge- Demand Charge Reduction

A significant issue uncovered during the EV Project was the imposition of demand charges on EV charging – most significantly observed in DC Fast Charging. Consequently, the EV Project issued a white paper on the subject summarized here and included as Appendix R.

These demand charges are charges levied by the utility, typically for commercial properties, for the peak power used during a billing cycle, regardless of the amount of energy drawn at this power rate. These demand charges can add significantly to the utility bill for an EVSE host and can make EVSE hosting cost prohibitive. While demand charges are incurred for the AC Level 2 EVSE hosts, the DCFC hosts' demand charge costs are likely to be more significant because of the much higher power draw by a DCFC.

For most U.S. utilities, the peak power for a given billing cycle is determined by calculating the average power in consecutive 15-minute intervals (from start to finish of the billing cycle) and extracting the highest average from the entire cycle of intervals. Some utilities will impose a demand charge for every kW of usage; others will impose no demand charge until a specified power threshold is surpassed. In some locations, the demand threshold was high enough (i.e. 50 kW) that a DCFC operating at full power on an independent circuit would not incur these charges.

Demand charges can become quite significant and can in fact dominate a utility bill in certain circumstances. A generic example of the effect of demand charges on a utility bill is shown below in Table 15 where the bills for a varying number of charged PEVs are shown, along with the cost per vehicle charged. In this example, the basic meter charge is \$200 (regardless

of the power and energy drawn by the EVSE); the demand charge is \$10/kW, a typical commercial value; and the energy charge is \$0.11/kWh, also a typical commercial value. Each PEV that is charged is assumed to use the full 60 kW available from the Blink DCFC for 20 minutes, for a total energy usage of 20 kWh per vehicle. A further assumption is that there is no other load on this particular meter. Implicit in this assumption is that this means that a new utility service is installed for the EVSE, and that the additional costs associated with a new service for the EVSE are ignored.

Table 15: Demand Charge Scenario

Scenario	Number of Vehicles Charged/ Month	Meter Charge	Demand Charge	Energy Charge	Monthly Total	Cost per Vehicle
1	0	\$200	\$0	\$0	\$200	N/A
2	1	\$200	\$600	\$2.20	\$802.20	\$802.20
3	10	\$200	\$600	\$22	\$822	\$82.20
4	100	\$200	\$600	\$220	\$1,020	\$10.20
5	250	\$200	\$600	\$550	\$1,350	\$5.40
6	500	\$200	\$600	\$1,100	\$1,900	\$3.80

Source: Blink Network

As shown in the above table, the demand charge remains constant regardless of the number of vehicles charged, and that it becomes proportionally less of the bill as the number of vehicles charged increases. Furthermore, as the number of vehicles charged increases, the overall cost per vehicle falls dramatically. If a sufficiently large number of vehicles use the EVSE to charge, the demand charge becomes less of a concern. However, since the number of vehicle customers cannot be estimated with any precision and the site owners may be unwilling to incur large demand charges, strategies to reduce or eliminate these charges must be developed.

While some of the utilities in the EV Project territories did not impose demand charges, the three utilities with the EV Project with the highest demand charge rates at the time of the paper were in California (these are given as the highest possible demand charge; demand charges may be lower at other times of the year and/or at other times of the day):

1. Los Angeles Department of Water and Power: \$9.00 per kW (high peak demand charge) plus \$5.00 per kW (Facilities charge), for a total of \$14.00 per kW.
2. Southern California Edison: \$17.05 per kW (summer demand charge) plus \$12.18 per kW (Facilities charge), for a total of \$29.20 per kW.
3. Burbank Water and Power: \$9.86 per kW (Billing Demand Charge), \$11.18 per kW (Special Demand Charge), for a total of \$21.04 per kW.

This became an important issue to finding enthusiastic charging site hosts for DCFC. The revenue collected from access fees to DCFC could not overcome the potential utility demand charges which would be billed to the host.

Consequently, mitigation methods are required.

In order to determine the method for reducing the demand charge, the first step is to determine the following parameters for a given location:

- What is the expected peak demand of the site owner in a billing period? Over how much of the 15-minute interval does the peak demand span?
- What is the average site demand?
- What is the utility rate structure? Is there a yearly maximum average power demand charge in addition to the billing cycle maximum average power demand charge?
- What is the demand charge tolerance?

Once these parameters are specified, the next step is to choose from the possible methods for reducing the demand charge. The six methods that have been identified are:

1. Never allow the overall site power demand to exceed a specified value.
2. Attempt to ensure that the average power over the interval is less than or equal to a specified value.
3. Attempt to recoup the demand charge cost through structured pricing for EVSE charging.
4. Add an energy storage system (i.e. local battery) that buffers the EVSE unit from high power demands during charging.
5. Aggregate demand among multiple EVSE installations into one demand charge calculation, taking advantage of the diversity that may exist in individual unit usage.
6. Provide demand response capability to the utility to either offset or circumvent demand charges.

The first two can be incorporated into the DCFC design but risk upsetting users who expect that the DCFC will deliver high power. Restricting the DCFC output may be a surprise to drivers who need to restore their battery to complete their travel. The third option may become cost prohibitive from the user's point of view and thus discourage use. The fourth option can provide certainty that the demand charges are minimized. This was the subject of a special project started by ECotality prior to the bankruptcy and continued by its successor in this area.

The fifth and sixth options offers demand charge reduction opportunities, but they both involve substantial negotiations with the electric utility. The sixth option is partially studied in the Smart Grid Demonstration conducted as part of the EV Project and reported elsewhere in this document.

Another option was added through negotiation with DCFC charging site hosts while the above were under study. That option required the EV Project to absorb the demand charges that exceeded the typical demand from the charging site host.

While electric utilities have been strongly supportive of the adoption of PEVs into the transportation sector, this topic is a strong counter incentive to the large-scale promotion of DCFC.

EVSE and EV Programming

In certain regions of the EV Project, electric utilities provide a rate structure that charges higher rates during their peak usage times and lower rates during the off-peak usage times compared to their basic or standard rate. The time-of-use (TOU) rates are established to provide incentives to their customers to shift their high electrical usage to the off-peak times. The effects of TOU rates were reported above. Taking advantage of these TOU rates requires that either the EVSE or the PEV have charge programming capabilities. The Blink EVSE provided in the EV Project and the Leaf and Volt have such capabilities. The EV Project desired to know the preferences of participants in programming their charge times. The resulting paper was posted to the EV Project website and is included here as Appendix Z.

While some but not all PEV suppliers include programming, some but not all EVSE suppliers provide programming capabilities. Taking advantage of the TOU would require one, the other or a third method for controlling the charge to occur on off-peak hours.

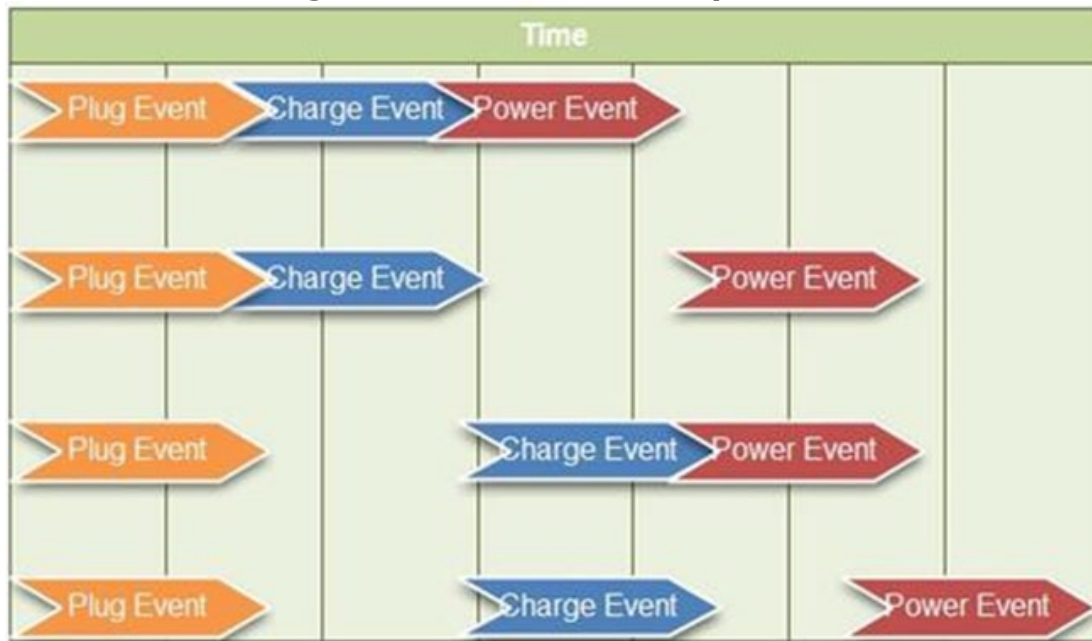
Among the many smart features of the Blink EVSE unit is its ability to provide event and charge information through the Blink Network to the database at ECOTality. Among the events provided are:

- **Plug-event start and stop:** indicate that the charge connector is inserted or removed from the vehicle charge port.
- **Charge event start and stop:** indicate that the contactor in the EVSE unit has closed or opened. A closed contactor means the EVSE is ready to charge the vehicle.
- **Power event start and stop:** indicate that charge current is flowing or has stopped flowing to the vehicle.

Once the EVSE unit is connected to the PEV and the contactor has closed, the charge is largely controlled by the PEV. While the EVSE unit signals the PEV its maximum current output capabilities, it is the PEV's on-board charger and battery management system (BMS) that monitors the on-board battery to determine the best way to conduct the recharge. It draws the amount of charge current necessary to provide this control. If the vehicle is programmed to schedule charge start and/or stop times, it determines when the battery will accept the charge. Both the vehicle and the EVSE unit must be set to charge before energy will flow to the vehicle.

Using the three types of EVSE events and knowledge of the BMS control, four possible scenarios are identified in the EVSE event data, as indicated in Figure 107.

Figure 107: EVSE Event Sequences



Source Blink Network

1. **No Program:** When the Plug, Charge and Power events happen at nearly the same time, it indicates that the connector has been plugged into the vehicle, the contactor has closed, and the charge has begun. No time delay would indicate that there is no program controlling the start of the charge.
2. **Vehicle Programmed:** The gap between the Charge event and the Power event indicates that the EVSE unit is ready to charge the vehicle, but the vehicle has not yet begun drawing power.
3. **EVSE Unit Programmed:** The gap between the Plug and Charge event followed immediately by the Power event indicates that the connector has been inserted into the vehicle but the EVSE unit is not allowing the charge to commence until later. Once the EVSE unit timer allows the charge, the contactor closes and the power flows.
4. **Both Programmed:** As in No. 3 above, the EVSE unit timer is active. However, because the power did not flow immediately upon the EVSE unit contactor closing, the vehicle is not allowing the charge. Thus, the participant has programmed both the PEV and EVSE.

The project studied the residential charge events in all regions of The EV Project to determine the preferences of the participants. Figure 108 provides the results.

Figure 108: Percent of Plug-In Events by Each EV Project Region

Percent of Plug-in Events				
Territory Name	Not Scheduled	Vehicle Scheduled	EVSE Scheduled	Both Scheduled
Atlanta	72%	10%	17%	1%
Chattanooga	83%	11%	5%	0%
Chicago	86%	8%	5%	1%
Dallas/FW	95%	3%	2%	0%
DC	87%	7%	6%	0%
Houston	93%	6%	1%	0%
Knoxville	78%	16%	5%	1%
Los Angeles	62%	18%	19%	1%
Memphis	85%	11%	4%	0%
Nashville	89%	5%	5%	0%
Oregon	75%	17%	7%	1%
Philadelphia	92%	4%	4%	0%
Phoenix	66%	17%	16%	1%
San Diego	38%	34%	25%	3%
San Francisco	43%	31%	23%	3%
Tucson	61%	24%	12%	2%
Washington State	82%	12%	5%	1%
Total	63%	21%	15%	2%

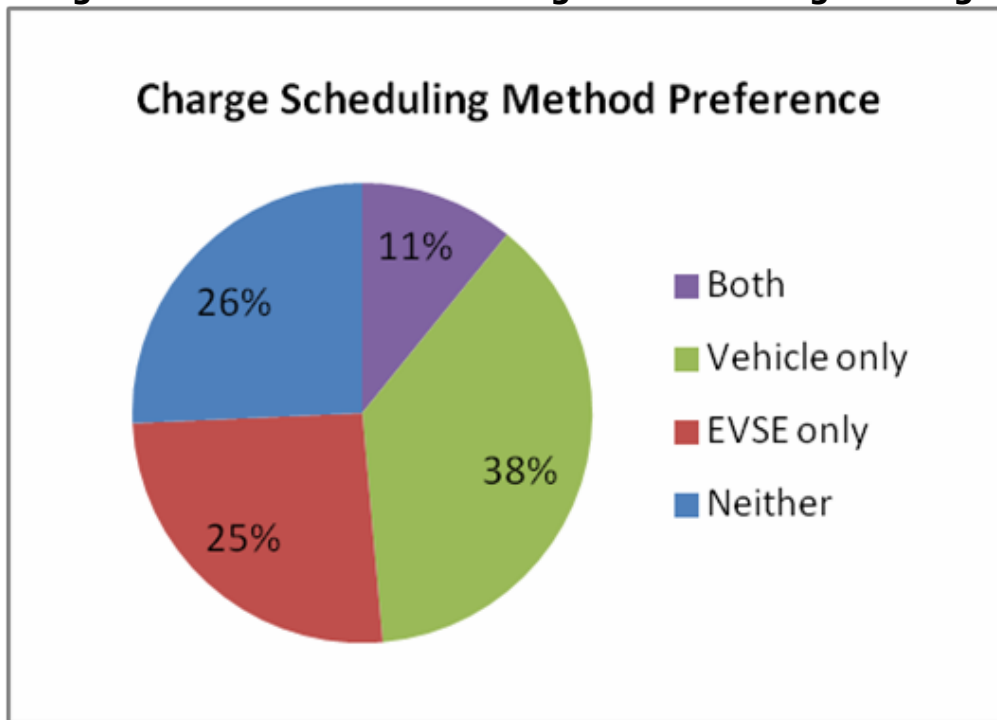
Source: Blink Network

Among the larger utilities providing TOU rates in The EV Project regions are Arizona Public Service (Phoenix region), Georgia Power (Atlanta region), Los Angeles Department of Water and Power, (Los Angeles region), Pacific Gas & Electric (San Francisco region), Portland General Electric (Portland region), Salt River Project (Phoenix region), San Diego Gas & Electric (San Diego region), Southern California Edison (Los Angeles region) and Tucson Electric Power (Tucson region). It is noteworthy that many in these service territories elect not to program either the PEV or the EVSE.

The behavior of The EV Project participants in two of these utility service territories was examined. The electric utilities were Portland General Electric and Pacific Gas and Electric (PG&E), which provide basic or standard whole-house rates and TOU rates. PG&E also provides an EV rate.

Residential EVSE usage data from 1,097 EV Project participants in these areas were analyzed to determine the percentage of participants who have and have not scheduled home charging in the last six months of 2012. Those who scheduled charging were broken into groups, based on whether they program their vehicle, EVSE, or both. Figure 109 shows the results.

Figure 109: Preference for Charge Schedule Programming



Source: Blink Network

Survey respondents commented on some technical aspects of charge schedule programming, which may confuse some users.

Respondents noted that there are potential conflicts if both the EVSE unit and PEV are programmed. If the PEV's programmed start time is before the EVSE's programmed start, the charge will not start until the EVSE unit programmed start is reached. Vehicle owners who have disconnected their vehicle before the programmed start time of the EVSE were disappointed when they found no charge had occurred.

If the vehicle is programmed to start charging at night and the PEV driver elects to charge at a publicly accessible EVSE unit during the day, the PEV programming must be overridden.

The programming on one of the PEVs is such that a charge will not initiate if the PEV is connected after the programmed start time unless overridden. That is, if the vehicle is programmed to start a charge at midnight and the connect event occurs at 12:05, the charge will not commence.

It has also been reported that if the vehicle is programmed to start before the EVSE unit, the vehicle can command the commencement of the charge, but stops it if no current flows. The vehicle will then not charge when the EVSE unit program actually closes the contactor. Some responders noted that they would like the EVSE unit to make charging decisions based upon the PEV battery's State of Charge (SOC). Vehicles do not yet make that information available to the EVSE.

Participants noted that once the programming is completed, it is very convenient to connect upon arriving home and letting the program control the charge.

Chapter 6: Conclusions

The original problem statement and the project's objectives were as follows:

Problem Statement

With production EVs available next year, the lack of infrastructure to support these vehicles is now a barrier to their widespread adoption and the realization of the potential they provide for petroleum reduction. The proposed Project takes advantage of the initial availability of Nissan EVs to develop, implement and study techniques for optimizing the effectiveness of infrastructure supporting widespread EV deployment. By studying and developing lessons learned from the infrastructure supporting these first 5,000 vehicles, the proposed Project enables deployment of the next 5,000,000 vehicles.

Goals of the Agreement

The goal of this Agreement is to study and develop lessons learned from the infrastructure supporting the first 5,000 EVs deployed, to enable deployment of the next 5,000,000 vehicles.

Objectives of the Agreement

The objectives of this Agreement are to;

- Deploy Level 2 charge infrastructure in residential applications to support EV sales in San Diego
- Deploy Level 2 charge infrastructure in commercial applications to support EV sales in San Diego
- Deploy Level 3 charge infrastructure to support EV sales in San Diego

As we look back with the benefit of hindsight on these statements and objectives which were defined over four years ago, there are key statements that warrant further examination.

This project was conducted at the beginning of the first widespread sale of Plug-In Vehicles in American history. The goal was to study and learn lessons from the deployment and use of the initial charging infrastructure supporting these initial vehicles. The goal was to be able to use this study to understand how better to support further adoption of Plug-In vehicles.

The stated objective of this agreement was to deploy charge infrastructure to support these new vehicles. In addition, and as this report identifies at the outset, collecting data on the deployment and use of the infrastructure is necessary to meet the project's stated goals to study and learn from the deployment and use.

Approach

The project's approach to meet the stated goals and objectives were to do the following:

- Establish and follow a plan for locating the charging infrastructure based on information and experience provided by local stakeholders and, industry experience.
- Deploy hardware that could be controlled via a network and could collect and transmit data on its use.

- Identify, train and qualify electrical contractors in the installation, commissioning and service of smart charging units.
- Establish partnership with Plug-In vehicle manufacturers to gain access to PEV drivers and the vehicle use data
- Establish network to collect, store and transmit collected use data.
- Promote via PEV partners, industry and internet/smart phone applications the study and the charging infrastructure to promote use and participation.
- Analyze collected information and disseminate through public postings and presentations.

This approach prepared the project for success. However, barriers existed which ultimately affected project cost and timing and forced amendments, modifications, and adjustments to expectations. Amongst these barriers were:

- local permitting processes made timely installations difficult
- vehicle sales were far below expected rates (even with steady growth, today PEVs only represent 0.3 percent of sales)
- charging site hosts were unwilling to commit dedicated parking spaces without vehicles to occupy them
- cost of installations
- upgrades to service relied on electric utility, which again added time to the process
- commitment from property ownership when not the property occupant

Achieving Goals & Objectives

The final objectives identified in this agreement regarding the deployment of charge infrastructure to support the various applications were:

- 1,025 Level 2 charging units for residential applications
- 800 Level 2 charging units for commercial applications
- 30 DC Fast Chargers

None of these specific hardware deployment objectives was met before the original awardee, Electric Transportation Engineering Corporation filed for bankruptcy in September 2013. The deployment achieved by that time and the percentage of the objective was:

- 953 Level 2 charging units for residential applications (93 percent)
- 552 Level 2 charging units for commercial applications (69 percent)
- 7 DC Fast Chargers (21 percent)

Meanwhile, the information on charging infrastructure deployment, on charging unit and vehicle use was largely achieved as this report has described in detail. All vehicle parameters and all charging parameters that were identified for study were collected and analyzed.

As for the stated goal to study the identify lessons learned, this report has described many of the observations on vehicle and charging infrastructure use over the two years of data collection. Many of these observations require context in order to learn something from the data collected. This report intended to do that as much as possible.

Achievements

In the end, there were two significant measures of the success of this project. The first is the quantifiable value of installing 80 percent of the intended infrastructure units and collecting 100 percent of the information on its use for 66 percent of the project budget.

The second refers to the historical timing of this project, which defined much of what was achieved by the project. The Oxford English Dictionary defines verb *Prime* as follows:

“Prepare (someone) for a situation or task, typically by supplying them with relevant information: *[with object and infinitive]: the sentries had been primed to admit him without challenge*”

Prime the Pump: Stimulate or support the growth or success of something by supplying it with money.

There is little doubt as we see the continuing growth of PEV sales, growth in use of away-from-home chargers (particularly DC Fast Chargers) and more and more employers providing workplace charging, that this project was successful at preparing for a situation and stimulating with money, and thus enabling California to play a very big part in deploying the next 5,000,000 vehicles.

GLOSSARY

ALTERNATING CURRENT (AC)—Flow of electricity that constantly changes direction between positive and negative sides. Almost all power produced by electric utilities in the United States moves in current that shifts direction at a rate of 60 times per second.

ALTERNATIVE AND RENEWABLE FUELS AND VEHICLE TECHNOLOGY PROGRAM (ARFVTP)—Now known as the Clean Transportation Program, created by Assembly Bill 118 (Nunez, Chapter 750, Statutes of 2007), with an annual budget of about \$100 million. Supports projects that develop and improve alternative and renewable low-carbon fuels, improve alternative and renewable fuels for existing and developing engine technologies, and expand transit and transportation infrastructures. Also establishes workforce training programs, conducts public education and promotion, and creates technology centers, among other tasks.

AMERICANS WITH DISABILITIES ACT (ADA)—ADA refers to the Americans with Disabilities Act of 1990 which is one of the most significant federal laws governing discrimination against persons with disabilities. This Act prohibits discrimination against individuals with disabilities in employment, housing, education, and access to public services. The ADA defines a disability as any of the following: 1. "a physical or mental impairment that substantially limits one or more of the major life activities of the individual." 2. "a record of such impairment." or 3. "being regarded as having such an impairment."

AMERICAN RECOVERY AND REINVESTMENT ACT OF 2009 (ARRA)—U.S. Congress passed the American Recovery and Reinvestment Act of 2009 on February 13, 2009, at the urging of President Obama, who signed it into law four days later. A direct response to the economic crisis, the Recovery Act strives to create new jobs and save existing ones, spur economic activity and invest in long-term growth, and foster unprecedented levels of accountability and transparency in government spending. Among its objectives, the act makes \$275 billion available for federal contracts, grants, and loans.

AUTHORITY HAVING JURISDICTION (AHJ)—An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

BATTERY ELECTRIC VEHICLE (BEV)—Also known as an "All-electric" vehicle (AEV), BEVs utilize energy that is stored in rechargeable battery packs. BEVs sustain their power through the batteries and therefore must be plugged into an external electricity source in order to recharge.

BATTERY MANAGEMENT SYSTEM (BMS)—Systems encompassing not only the monitoring and protection of the battery but also methods for keeping it ready to deliver full power when called upon and methods for prolonging its life. This includes everything from controlling the charging regime to planned maintenance.

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

1. Forecasting future statewide energy needs
2. Licensing power plants sufficient to meet those needs
3. Promoting energy conservation and efficiency measures
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels
5. Planning for and directing state response to energy emergencies.

CARBON DIOXIDE (CO₂)—A colorless, odorless, nonpoisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO₂ is the greenhouse gas whose concentration is being most affected directly by human activities. CO₂ also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent).

CARBON DIOXIDE EQUIVALENT (CO₂e)—A metric used to compare emissions of various greenhouse gases. It is the mass of carbon dioxide that would produce the same estimated radiative forcing as a given mass of another greenhouse gas. Carbon dioxide equivalents are computed by multiplying the mass of the gas emitted by its global warming potential.

CUSTOMER RELATIONSHIP MANAGEMENT (CRM)—Refers to all strategies, techniques, tools, and technologies used by enterprises for developing, retaining, and acquiring customers.

DIRECT CURRENT (DC)—A charge of electricity that flows in one direction and is the type of power that comes from a battery.

DIRECT CURRENT FAST CHARGING (DCFC)—Direct-current fast charging equipment (typically 208/480V AC three-phase input), enables rapid charging along heavy traffic corridors at installed stations. As of 2019, about 15% of charging outlets in the United States were DC fast chargers. There are three types of DC fast charging systems, depending on the type of charge port on the vehicle: SAE Combined Charging System (CCS), CHAdeMO, or Tesla.²⁸

ELECTRIC VEHICLES (EV)—A broad category that includes all vehicles that are fully powered by Electricity or an Electric Motor.

ELECTRIC VEHICLE CHARGING STATION (EVSE)—Infrastructure designed to supply power to EVs. EVSE can charge a wide variety of EVs including BEVs and PHEVs.

EXTENDED-RANGE ELECTRIC VEHICLE (EREV)—Uses only the electric motor to drive the wheels. The internal combustion engine is used to generate electricity for the motor.³⁹

FULL-TIME EQUIVALENT (FTE)—A unit that indicates the workload of an employed person in a way that makes workloads (or class loads) comparable across various contexts. FTE is often used to measure a worker's (or student's) involvement in a project, or to track cost reductions in an organization. An FTE of 1.0 is equivalent to a full-time worker or student.⁴⁵

GLOBAL POSITIONING SYSTEM (GPS)—An accurate worldwide navigational and surveying facility based on the reception of signals from an array of orbiting satellites.

²⁸ US Department of Energy, Alternative Fuels Data Center, [Electric Charging Infrastructure Webpage](https://afdc.energy.gov/fuels/electricity_infrastructure.html): https://afdc.energy.gov/fuels/electricity_infrastructure.html

GREENHOUSE GAS (GHG)—Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (NO_x), halogenated fluorocarbons (HCFCs), ozone (O₃), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

IDAHO NATIONAL LABORATORY (INL)—In 1949, the Naval Proving Ground became the National Reactor Testing Station (NRTS). In 1974, NRTS was granted national laboratory status and renamed Idaho National Engineering Laboratory. Congress designated the U.S. Department of Energy's 890-square-mile installation on the Idaho desert as the nation's lead nuclear energy research, development and demonstration laboratory, and in 2005, INL was born.²⁹

INTERNAL COMBUSTION ENGINE (ICE)—The ignition and combustion of the fuel occurs within the engine itself. The engine then partially converts the energy from the combustion to work.

KILOWATT (kW)—One thousand watts. A unit of measure of the amount of electricity needed to operate given equipment. On a hot summer afternoon, a typical home with central air conditioning and other equipment in use might have a demand of 4 kW each hour.

KILOWATT-HOUR (kWh)—The most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

MASTER GEOGRAPHIC REFERENCE AREA (MGRA)—The base unit of geography for the model was MGRA, a proprietary data unit designed and used by SANDAG. MGRAs are roughly the size of census blocks in urban and suburban areas, and census block groups in rural areas. MGRAs are designed to nest to larger standard geographies such as census tracts, zip codes, and municipal boundaries. They are delineated in a way to preserve the contiguity of trip producing and attracting land uses.³⁰

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)—A non-regulatory agency created to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve quality of life.

NATIONAL RENEWABLE ENERGY LABORATORY (NREL)—The National Renewable Energy Laboratory (NREL), located in Golden, Colorado, is the United States' primary laboratory for renewable energy and energy efficiency research and development. NREL is the only Federal laboratory dedicated to the research, development, commercialization, and deployment of renewable energy and energy efficiency technologies.

ORIGINAL EQUIPMENT MANUFACTURER (OEM)—refers to the manufacturers of complete vehicles or heavy-duty engines, as contrasted with remanufacturers, converters, retrofitters,

²⁹ Idaho National Laboratory. 2020. "[Welcome to INL Fact Sheet](https://factsheets.inl.gov/FactSheets/WelcomeToINL.pdf)." <https://factsheets.inl.gov/FactSheets/WelcomeToINL.pdf>

³⁰ ECotality, "[EV Micro-Climate Plan for San Diego Region](https://avt.inl.gov/sites/default/files/pdf/EVProj/102060-328106.mcp-san.pdf)." 2011. <https://avt.inl.gov/sites/default/files/pdf/EVProj/102060-328106.mcp-san.pdf>

up-fitters, and re-powering or rebuilding contractors who are overhauling engines, adapting or converting vehicles or engines obtained from the OEMs, or exchanging or rebuilding engines in existing vehicles.

PACIFIC GAS AND ELECTRIC COMPANY (PG&E)—An electric and natural gas utility serving the central and northern California region.

PLUG-IN ELECTRIC VEHICLE (PEV)—A general term for any car that runs at least partially on battery power and is recharged from the electricity grid. There are two different types of PEVs to choose from—pure battery electric and plug-in hybrid vehicles.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV)—PHEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The vehicle can be plugged in to an electric power source to charge the battery. Some can travel nearly 100 miles on electricity alone, and all can operate solely on gasoline (similar to a conventional hybrid).

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)—A global association of more than 128,000 engineers and related technical experts in the aerospace, automotive, and commercial-vehicle industries. The leader in connecting and educating mobility professionals to enable safe, clean, and accessible mobility solutions.

SOUTHERN CALIFORNIA EDISON (SCE)—One of the nation's largest electric utilities, which delivers power to 15 million people in 50,000 square miles across central, coastal, and Southern California, excluding the City of Los Angeles and some other cities.

SAN DIEGO GAS AND ELECTRIC (SDG&E)—The acronym for San Diego Gas & Electric an electric and natural gas utility serving the San Diego, California, region.

STATE OF CHARGE (SOC)—Available capacity expressed as a percentage of its rated capacity.

TIME-OF-USE (TOU)—PG&E rate plans that can reduce expenses by shifting energy use to partial-peak or off-peak hours of the day. Rates during partial-peak and off-peak hours are lower than rates during peak hours.

UNITED STATES DEPARTMENT OF ENERGY (U.S. DOE)—The federal department established by the Department of Energy Organization Act to consolidate the major federal energy functions into one cabinet-level department that would formulate a comprehensive, balanced national energy policy. DOE's main headquarters are in Washington, D.C.

VOLT (V)—A unit of electromotive force. It is the amount of force required to drive a steady current of one ampere through a resistance of one ohm. Electrical systems of most homes and offices have 120 volts.